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THE AEROBIC COST OF EXERCISE
AS A
DETERMINANT OF ENDURANCE FITNESS

BY

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ABSTRACT

The purpose of this study was to determine whether the aerobic cost of training is a critical determinant of endurance fitness if the total oxygen cost, frequency of the training sessions and the initial fitness levels within each group were equated.

Thirty-six subjects (mean age 37.4 years) were ranked according to $M\dot{V}O_2$ in ml per kg per minute and the blocked into three fitness levels. The subjects from each fitness level were then randomly assigned to one of three groups. The first group (T70) trained at 70% of their $M\dot{V}O_2$; the second group (T50) trained at 50% of their $M\dot{V}O_2$ and the third group acted as a control. The training was accomplished on a bicycle ergometer and the program consisted of three sessions per week for eight weeks. The total oxygen cost was equated in both training groups for each training session and over the whole training program.

After the training, significant decreases in blood lactate concentrations occurred for both training groups over the control at a submaximal work load (900 Kpm). There was no differences at this work load, however, between the two training groups.

Significant decreases in heart rate, blood lactate concentrations, pulmonary ventilation and the ventilatory equivalent occurred for both training groups over the control at the work load which produced $M\dot{V}O_2$ on the initial test. There was no difference at this work load, however, between the two training groups.

Significant increases in maximum work load, maximum oxygen consumption and blood lactate concentrations for both training groups over the control were found after training. There was no differences between the two training groups.

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CHAPTER 1

INTRODUCTION

Recently in the field of exercise physiology there has been an increasing recognition that cardio-respiratory fitness or endurance fitness is the key to overall conditioning since it is intimately related to the oxygen transfer process in the pulmonary system as well as at the cellular level of the working tissue. Investigators today (4,7,10,23,102) are using maximum oxygen uptake as the more acceptable measure of endurance fitness since it is a measure of the limit to which this oxygen transfer process within the body can be taxed. Endurance fitness also implies an increased ability of the body to use anaerobic energy reserves and increased ability to tolerate anaerobiosis.

Many exercise physiologists have concerned themselves with the selection of an optimum or minimum training regime necessary to bring about desired improvements in endurance fitness. The training stimuli (intensity, frequency and duration) have been used as the independent variables with various cardio-respiratory parameters as the dependent variables. Current literature relating to the respective importance of these three training stimuli have recently been reviewed (65,109). While general theories of stress adaptation emphasize intensity rather than duration, the specific application of these generalizations to endurance fitness have not been firmly established.

Some authors have stressed the existence of a critical training

threshold below which no training will occur. Karvonen et al. (54) Sharkey and Hollman (89), and Molloy (69) all trained male subjects between the ages of 17 to 24 years, and contend that to improve the excercise tolerance of the cardiovascular system the heart rate during training must be 140 or 150 beats per minute. However, this concept has not been substantiated by other laboratory studies. Durnin et.al. (32), Petersen (74), and Bouchard et.al. (13) found that quite mild exercise is effective to changes in endurance fitness.

Cooper (23) has devised an exercise point system in which one point is equal to seven millilitres of oxygen per kilogram of body weight. He states that if one earns thirty points a week a good "endurance fitness" can be maintained. The crux of the point system is that an energy expenditure of 35 ml per kg per min., sustained for at least five minutes is worth five points. The exercise points system is based on two principles, first, if the intensity of exercise is enough to produce a sustained heart rate of 150 beats per minute or more, the training effect benefits begin about five minutes after the exercise commences and continue as long as the exercise is performed, and second, if the exercise is not intense enough to produce or sustain a heart rate of 150 beats per minute, but is still demanding oxygen, the exercise must be continued considerably longer than five munutes, the total period of time depending on the oxygen consumed. The key to his system is that each exercise requires a certain amount of oxygen. This oxygen requirement can be measured so that each excercise is assigned a certain number of points, based on the amount of oxygen required

to perform it.

THE PROBLEM

To determine whether the aerobic cost of a training program of varying intensity and duration is a critical determinant of endurance fitness. Aerobic cost is the amount of oxygen used by an individual during work including the amount of oxygen used at a resting state and was equated over the whole group of subjects during the training period.

JUSTIFICATION OF THE STUDY

Several authors (13,32,54,65,69,74,77,89,94,109) have investigated the effects of intensity, frequency and duration of exercise on endurance fitness. However no attempt was made by any of the authors to equate the oxygen cost of the subjects.

On close examination of the points system (23) it is quite evident that the system is based on intensity. For example, if an individual runs a mile in 12 minutes, 21 ml per kg per min. will be consumed which is equal to 252 ml of oxygen and worth three points. The same individual can run a mile in six minutes using up 42 ml per kg per min., which is equal to 252 ml of oxygen, but is now worth six points. In other words, an individual must run two miles in 24 minutes consuming 21 ml per kg per min., equal to 504 ml of oxygen to earn six points, the same points as the six minute miler consuming only 252 ml of oxygen. Unless a very strong evidence to the contrary is available, equal points should be awarded for an equal energy expenditure over a given time.

Research is required for the selection of an optimum training regime, both in the preparation of athletes and for the promotion of "fitness" within the community. Any training regime that is unnecessarily severe, prolonged, or frequent could have a deleteriosis effect upon performance. Furthermore, in the case of the general public, it is necessary to establish minimal amounts of training or exercise to develop endurance fitness, in order to maintain interest in exercise programs.

DELIMITIONS OF THE STUDY

The study involved thirty-six members of the Edmonton Police Department who volunteered to take part.

LIMITATIONS OF THE STUDY

Although the subjects were asked to maintain the same activity patterns engaged in before the study, it was impossible to control the activities outside the laboratory training sessions.

The same maximal work loads for both the pre and post testing sessions were used for the control group unless the heart rate had not reached the same level. It was felt that the risk of injury was too high if subjects of this age group and low fitness were worked too hard without training.

Maximal oxygen intake can be affected by temperature variation when testing (80,105). The temperature in the laboratory was, therefore, maintained thermostatically at 22 $\pm$ 2^{o}C but the relative humidity was not controlled.

The collection of the expired air sample was timed by a stopwatch for one minute without regard to the breathing cycle.

DEFINITIONS AND ABBREVIATIONS OF TERMS

Aerobic Work: A given amount of work for which the oxygen supply is sufficient, and recovery keeps pace with activity.

Anaerobic Work: The accomplishment of a given amount of work when the oxygen cost per minute always exceeds the oxygen intake. During severe exercise, oxygen intake is inadequate to supply the oxygen requirement for production of the energy demanded, and the energy for muscular contraction is derived anaerobically from a complex series of chemical reactions sometimes referred to as anaerobic energy processes.

ANOVA: Analysis of Variance

Blood Lactate (HLa): The lactic acid which is in the blood in the combined state with the blood buffers. Lactic acid is the end product of anaerobic metabolism of carbohydrate and is used as a measure of the extent to which the anerobic energy supply mechanism has been engaged.

Initial Maximal Work Load: The work load at which a subject reached maximum oxygen consumption on the pre training test.

Kilopond: 1 kp. is the force acting on the mass of 1 kg. at normal acceleration of gravity.

Kilopond Metre (kpm): A measure of work on a bicycle ergometer. Product of tension x distance travelled by wheel in 1 revolution x number of revolutions per min.

Maximal Heart Rate: The heart rate attained by a subject when he has reached a maximal oxygen consumption.

Maximal Oxygen Intake = Maximum Oxygen Uptake = Maximum Oxygen Consumption = $M\dot{V}O_2$ = Aerobic Power: A test of the maximal capacity of the cardi-respiratory system to take up, transport, and give off oxygen to the working tissues, and for these tissues to use the oxygen, corrected to STPD.

Oxygen Cost ($\dot{V}O_2$): The amount of oxygen (STPD) extracted from the inspired air in ml per kg per min. For the purposes of this study it was defined as the steady state oxygen cost of exercise, disregarding recovery oxygen.

Oxygen Pulse ($\dot{V}O_2$/HR): The amount of oxygen consumed per heart beat. This is used as a measure of cardio-respiratory efficiency and expressed in ml. (STPD) per beat.

Pulmonary Ventilation ($\dot{V}E$): The volume of air expired per minute and measured in litres at standard temperature and pressure, dry (STPD).

Ventilatory Equivalent ($\dot{V}E/\dot{V}O_2$): The pulmonary ventilation per litre of oxygen consumed per minute. This index is used as a measure of pulmonary efficiency.

CHAPTER II

REVIEW OF LITERATURE

ESTIMATE OF OXYGEN COST FROM RATE OF WORK

Maritz et. al.(63) examined the premises upon which the Astrand-Rhyming Nomogram was based. One of the premises, that oxygen intake of the individual deviates very little from the mean straight line relating oxygen intake and rate of work for the population, was substantiated. Using African mine labourers, they examined the magnitude of the individual variations around the population mean Oxygen uptake, Work line.

$$O = A_2 + B_2 W$$

Each individual in the population has his own O,W straight line, $O = \alpha_2 + \beta_2 W$, where A_2 and B_2 are the population means of α_2's (y intercepts) and β_2's (slopes) respectively. The success of their proposal depended upon the variations between α_2's and β_2's from one individual to another. The random error in estimating O from a 'standard' O,W graph was calculated and was less than the variances of measured O due to error and physiological variation, being of the order 0.002 compared with 0.02. The individual straight lines of the twenty-six men were so similar, that any one of them could have been used with little error to estimate oxygen intake from work on a bicycle ergometer.

Durnin and Namyslowski (33) studied the variation of the gross metabolism or energy expenditure of ten men and ten women in four standardized activities. These activities were lying, sitting, walking on a treadmill on the level at 3.2 m.p.h., and walking on an incline up a 1 in 10 gradient at 2.7. m.p.h. Each activity was measured once daily at one of four different times (11 a.m., 12 noon, 2 p.m., and 3 p.m.) on four different days. The results showed no significant effect due to time of day or day.

Davies, Tuxworth and Young (30) studied five healthy male subjects on 16 days during a period of three weeks. The regression lines of oxygen intake ($\dot{V}O_2$) on work load (w) for each subject were calculated for the first and final experimental occasion. The mean $\dot{V}O_2$ data at a work load of 900 kpm per min. were substantially in agreement with the data of Astrand (1) for pedalling the stationary ergometer. The calculated mechanical efficiencies of their subjects were very close to the normal 23% (range 20 - 25%). Neither the individual nor the group regression lines of $\dot{V}O_2$ on W were significantly different from Day 1 to Day 16, and thus the $\dot{V}O_2$ at given W remained unchanged throughout the experimental period.

THE DEVELOPMENT OF CARDIO-RESPIRATORY FITNESS

EFFECT OF TRAINING ON $M\dot{V}O_2$

Bouchard, Hallman and Herkenrath (13) trained eight adult subjects for eight weeks, exercising them on a bicycle ergometer

for 10 minutes per day. The load was adjusted to produce a steady pulse rate of 130 per min., averaging 612 kgm per min. at the beginning and 912 kgm per min. at the end of the study. Maximal oxygen intake (measured directly) increased by 13% despite the low intensity and short duration of individual training periods.

Cureton and Phillips (28) trained six sedentary, middle-aged subjects for one hour per day, six days per week for eight weeks. The training program consisted of fifteen minutes of calisthenics, thirty to fifty minutes of cross country running, and thirty minutes of handball or squash. A 35% increase in $M\dot{V}O_2$ was observed after the eight week program. After an eight week rest the $M\dot{V}O_2$ levels of the subjects returned to the approximate pre-training values. The same training program, only with the intensity increased, was given for another eight weeks. An improvement increase of 93% in $M\dot{V}O_2$ values was observed over the pre-training $M\dot{V}O_2$ values.

Durmin, Brockway, and Whitcher (32) examined the effects of prolonged exercise of relatively low intensity (daily marches of 10, 20, or 30 km. at a speed of approximately 3.0 - 3.5 m.p.h.). Over the 10 day period of observation there was a greater increase of up to 13% in predicted $M\dot{V}O_2$ for the men walking 20 km. per day.

Ekblom et. al. (37) trained ten healthy male subjects (aged 19 - 27) for forty-five to seventy-five minutes per day, three days per week for sixteen weeks. The training program consisted of cross country endurance running interspersed with

interval sprints. $M\dot{V}O_2$ (measured on a bicycle ergometer) increased 16.2% (3.15 to 3.68 litres per minute) over the training program and was attributed to an increased cardiac output and an increased arterio-venous oxygen difference.

Ekblom (35) trained seven boys (aged 11) for six months, forty-five to sixty minutes per day, twice a week. The training program consisted of interval running, distance running, weight training, and ball games. An increase of 15% in $M\dot{V}O_2$ (measured on a bicycle ergometer) occurred over the training program with no change in the controls.

Hanson et. al.(46) trained 25 men (aged 40 - 49) three times weekly for seven months, each session lasting 1 to 1½ hours. The basic program consisted of muscle stretching and flexibility exercises, combined isometric-isotonic maneuvers with an Exer-Genie, calisthenics, and running. Each man was advised to set his own limit for each exercise and to try to increase this limit in successive sessions. After several weeks, team activities such as volleyball, paddleball, badminton, and basketball were instituted. Maximal oxygen uptakes increased by 18%.

Hartley et. al.(47) trained fifteen healthy male subjects (aged 38 - 55) for thirty minutes per day, two to three days per week, for eight to ten weeks. The training consisted of only distance running. $M\dot{V}O_2$ increased 14% (2.68 to 3.06 litres per minute) over the training session attributed to an increase of 13% in maximal cardiac output since $A\text{-}\dot{V}O_2$ difference did not change. This increase in maximal cardiac output was due to a

16% increase in stroke volume since heart rates at maximum showed no significant change due to the training.

Massicotte (65) trained thirty-six subjects (aged 11 - 13) on a bicycle ergometer three times a week, twelve minutes per session for six weeks. The subjects weredivided into four treatment groups after being blocked into three fitness levels. The first group trained at a heart rate of 170 - 180 bpm; the second group trained at a heart rate of 150 - 160 bpm; the third group trained at a heart rate of 130 - 140 bpm; and the fourth group acted as a control. $M\dot{V}O_2$ increased only in the first group after the duration of the training.

Naughton and Balke (72) trained six sedentary individuals, in a running program, five days per week for sixteen weeks. $M\dot{V}O_2$ (Measured on a treadmill) increased 43.3% (31.6 to 45.3 ml per kg per minute) over the duration of the program. Body weight only decreased by 2.6% (79.5 kg to 77.4 kg)

Naughton and Nagle (73) trained eighteen men (aged 41 years) for thirty minutes per day, three days per week, for seven months. The program consisted of a warm-up, calisthenics, and intermittent running with intensity gradually increased throughout the program. $M\dot{V}O_2$ increased by 15.3% (31.3 to 36.1 ml per kg per minute) over the training program.

Petersen (74) exercised thirty-six young men and sixteen young women on a bicycle ergometer five times per week for six weeks. All subjects performed the same total amount of work (19,500 kgm per day for the men, 13,500 kgm per day for the women),

but different groups were required to exercise for 7.5, 15, or 30 minutes per day. Improvements in cardio-respiratory fitness were assessed from the responses to a standard sub-maximal test. Evidence obtained showed that the longest period of exercise produced the greatest training effect (a decrease of pulse rate equivalent to a 25 - 30% increase of predicted maximal oxygen consumption).

Pollock, Cureton, and Greninger (76) divided twenty-seven subjects (aged 28 - 39) into two training groups and a control group. The program consisted of continuous walking, running or jogging in sessions lasting thirty minutes. Group 1 trained twice per week while Group 2 trained four times per week for twenty weeks. The control group did not exercise. $M\dot{V}O_2$ was measured on a treadmill prior to, middle of and at the end of the twenty weeks. Group 1 showed an increase of 17% in maximal oxygen uptake of the twenty week program while Group 2 increased 35% over the same period.

Ribisl (77) trained fifteen sedentary middle-aged men (aged 40.2 years) for thirty-five minutes per day, three days per week, for five months. The training sessions consisted of calisthenics, interval running, and cross country running. The author estimated a calorie cost of 300 kcal per hour per training session in the first month and 750 kcal. per hour in the final month. $M\dot{V}O_2$ (measured on a treadmill) showed a 14% improvement (40.1 to 45.5 ml. per kg. per minute) over the five months.

Saltin et. al. (83) investigated the effects of bed rest and training on six male subjects (aged 19 - 21). They were

tested in a control state, after twenty days of bed rest, and again after fifty-three to fity-five days of training. The training consisted of both interval and continuous running, and was carried out for about one hour per day, six days per week. $\dot{V}O_2$ values were near maximum during the interval running and between 65 - 90% maximum values during the continuous running. $M\dot{V}O_2$ increased 33% over the control values, and was attributed to increased stroke volume (17%) and increased arterio-venous oxygen difference (5.6%).

Saltin, et. al.(85) trained forty-two middle-aged subjects (mean age 40.5 years) twenty-five minutes per day, two to three days per week, for eight to ten weeks in a program consisting of walking, jogging, strength exercises and a two-mile run. Twice per week the running was of an intermittent nature (taxing 98 - 99% of the aerobic capacity), and the three session involved continuous running (taxing 91 - 97% of the aerobic capacity). $M\dot{V}O_2$ (measured on a bicycle ergometer) showed a 19% improvement (2.89 litres to 3.44 litres per minute) over the training program.

Seigel, Blomquist and Mitchell (87) trained nine blind men (aged 32 - 59) twelve minutes per day, three days per week for fifteen weeks on a bicycle ergometer. The training consisted of three, four minute exercise periods with a four minute rest between the exercise periods. The training elicited heart rates averaging twenty-seven beats below maximum values. Maximum oxygen uptake was measured directly and increased by 10% (24.0 to 28.5 ml per kg per minute) over the fifteen weeks.

Shepard (94) trained twenty-five subjects at one of three intensities (35%, 65%, and 90% of their maximum oxygen uptake) for one of three durations (5, 10 or 20 minutes per day) for one of three frequencies (1, 3 or 5 times per week). After six to ten training sessions $M\dot{V}O_2$ increased 5% (35.6 to 37.4 ml per kg per minute) in the low intensity group and 12% (35.6 to 40 ml per kg per minute in the high intensity group. Although he mentioned gross oxygen cost he failed to equate the groups on it. The author reports that the best combination involves maximum intensity, frequency, and duration of effort.

Wenger (109) trained thirty-six subjects (mean age 27.9 years) on a bicycle ergometer three times per week for seven weeks. The subjects were initially ranked according to $M\dot{V}O_2$ in ml per kg per minute and then blocked into four fitness levels. The subjects from each fitness level were then randomly assigned to one of three groups. The first group trained at 100% of the work load which produced $M\dot{V}O_2$; the second group trained at 60% of the work load which produced $M\dot{V}O_2$; and the third group acted as a control. The total work in both training groups were equated by having subjects of similar initial fitness in the different training groups perform the same work output. The $M\dot{V}O_2$ in ml per kg per min. showed a substantial increase in both training groups over the control group after the seven week program. The first group also had a significantly greater $M\dot{V}O_2$ than the second training group.

Maximal oxygen uptake values have been shown to increase from 5% to 35% due to training program varying in intensity and

duration. None of the researchers, however, attempted to equate oxygen uptake of the training groups. In one study (34) maximal oxygen uptake increased twice the value than another training group which had only trained half the time.

THE EFFECT OF TRAINING ON HEART RATE

Brouha (15) measured the heart rates at maximal loads of twenty-one subjects from a rowing team. Following a training program the heart rate at the same maximal loads showed a 7.3% decrease (191 to 177 beats per minute).

Davies, Tuxworth and Young (30) reported a significant decrease in heart rate (145 to 124 beats per minute) at a submaximal load, after seven days of training. There was no decrease in the maximal heart rate.

Durnin, Brockway and Whitcher (32) found a significant decrease in heart rate at submaximal loads in both the twenty km per day training group and the thirty km per day training group.

Ekblom et. al.(37) trained ten male subjects for sixteen weeks. They reported a significant decrease in heart rate (13 beats per minutes) at submaximal loads. The heart rate at the previous maximum decreased from 200 to 179 beats per minute and there was a significant decrease in maximal heart rates (200 to 192 beats per minute).

Hartley et. al.(47) trained fifteen sedentary male subjects (aged 38 - 55) for eight to ten weeks. They found a significant decrease in heart rate (161 to 144 beats per minute) at a submaximal work load of 900 kpm per minute as a result of the training. A significant decrease in maximal heart rate (182 to

176 beats per minute) also occurred.

Karvonen, Kentala and Mustala (54) exercised six male medical students on a treadmill for thirty minutes per day, four to five times per week for four weeks, at speeds of 9 - 14 km per hour. The speed of running was adjusted to maintain a predetermined terminal pulse rate for each individual. No training occurred in subjects with a terminal pulse rate of 135 beats per minute, but in other subjects a 25 - 30% increase of speed was necessary to maintain a pulse rate of 160 - 180 beats per minute. About half of this improvement occurred in the first week of training.

Massicotte (65), in children aged 11 to 13, found a significant decrease in heart rate at a given submaximal work load (450 kpm per minute) in the three training groups as compared to the control group. He found no changes in the maximum heart rate in the four treatment groups over the six week training program.

Naughton and Nagle (73) trained eighteen male subjects (mean age 41 years) for seven months. There was a significant decrease in the heart rate (167 to 156 beats per minute) at submaximal work load on the treadmill (12% grade, 3.4 m.p.h.).

Pollock, Cureton and Greninger (76) trained nineteen sedentary men (mean age 32.5 years) for either two times per week or four times per week, for twenty weeks. The maximal heart rate decreased significantly (from 187.8 to 180.2 beats per minute) for the four times per week group over ten weeks and decreased significantly (from 186.2 to 181.9 beats per minute) for the twice

per week training group over twenty weeks.

Ribisl (77) found no significant decrease in the maximum heart rate after training fifteen subjects (mean age 40.2) for five months with a running program.

Saltin et. al.(83) showed a significant decrease in heart rate (129 to 115 beats per minute) at a submaximal work load requiring 1.5 litres of oxygen per minute after a fifty-five day training program. The maximal heart rate showed no significant change (193 to 191 beats per minute).

Saltin et. al.(85) trained forty-two middle aged subjects (aged 34 - 50 years) for eight to ten weeks. They found a decrease in heart rate (155 to 138 beats per minute) at a submaximal work load of 900 kpm per minute. The maximal heart rate also decreased (190 to 183 beats per minute) over the training period.

Shepard (93) trained forty-five men for fifteen minutes, three times daily, at a load of 840 kpm per minute. A decrease in exercise pulse rate of 15 beats per minute occurred largely in the first four rides of the series. In a second group of men where the rides were prolonged to thirty minutes, three times daily, there was a somewhat smaller improvement in excercise pulse rate of only 10 beats per minute. Thirty minute rides at a lower intensity of effort (550 kpm per minute) produced only a small decrease of 5 beats per minute in the excercise pulse rate.

Swenson and Zauner (100) trained ten males (aged 36 - 56 years) five days a week, for eight weeks, for approximately one hour per day. The training consisted mostly of running, in which the distance and the intensity were progressively increased during

the training period. The heart rate decreased (from 141 to 115 beats per minute) at a give submaximal work load (3 m.p.h., 5% grade) after the training.

Wenger (109) found a significant decrease in the heart rate at the initial maximum work load for the two training groups as compared to the control group following a seven week training program. There was no significant difference between the two training groups.

It has been pointed out that training programs of low intensity to high intensity have produced significant decreases in heart rate over control groups at given submaximal work loads. Heart rate at the initial maximum work loads have also been shown to decrease. There is not a general agreement on what happens to the maximum heart rate. Some studies have shown a decrease in maximum heart rate while others have shown no change.

THE EFFECT OF TRAINING ON THE OXYGEN PULSE

Hermansen and Andersen (48) utilized the ratio of oxygen consumption to the heart rate in a study giving the amount of oxygen consumed a measure of cardio-respiratory efficiency. The oxygen pulse at maximal work was much high for athletes than for the sedentary subjects (27.2 versus 17.0).

Massicotte (65) found no significant changes in oxygen pulse between any of the groups at the submaximal work load. However, the oxygen pulse increased by 13% for the high intensity group at maximal load after training.

Pollock, Cureton and Greninger (76) showed a significant

increase in the maximum oxygen pulse (16.6 to 19.81 ml per beat) over ten weeks in a group that trained four times per week. The second group that trained twice per week for twenty weeks also increased the maximum pulse significantly (16.32 to 21.65 ml per beat) as a result of the training.

Ribisl (77) showed increases that are similar to those reported above. After a five month training program the maximal oxygen pulse increased significantly (19.0 to 21.2 ml per beat).

Wenger (109) reported that both training groups had significantly higher maximum oxygen pulse values following training than did the control. However, the difference between the two training groups was not significant.

The general consensus of the studies above indicate that the maximum oxygen pulse increases due to training.

THE EFFECT OF TRAINING ON PULMONARY VENTILATION

Durnin, Brockway and Whitcher (32) trained forty-five subjects for two weeks. Pulmonary ventilation was measured prior to, during, and after the training program. There was a significant decrease in pulmonary ventilation (61.0 to 55.3 litres per minute BTPS) for only the 20 km per day training group. The submaximal test was performed walking on a treadmill at 5.6 km per hour for fifteen minutes at a 10% grade.

Ekblom et. al.(37) trained ten male subjects in a program of cross country and interval running for sixteen weeks. There was a decrease in pulmonary ventilation (113.4 to 93.3 litres per minute at BTPS) at the initial maximum load and an increase in

pulmonary ventilation (113.4 to 127.5 litres per minute at BTPS) at the new maximum load.

Hartley et. al.(47) reported a decrease in pulmonary ventilation (64.1 to 61.7 litres per minute at BTPS) at a submaximal work load as a result of a training program.

Hermansen and Andersen (48) compared fourteen top athletes and twelve students in a horizontal study. The pulmonary ventilation at maximum work load for the athletes was 118 ± 5 litres per minute (BTPS) as compared to 83 ± 4 litres per minute (BTPS) for the students.

Massicotte (65) found no significant changes in submaximal or maximal pulmonary ventilation as a result of his training program using children as subjects.

Naughton and Nagle (73) reported a decrease in pulmonary ventilation (69 to 74 litres per minute BTPS) of eighteen men (mean age 41) on a submaximal treadmill test administered prior to, and following a training program.

Pollock, Cureton and Greninger (76) trained nineteen men for twenty weeks. The maximum pulmonary ventilation increased 127.2 to 137.9 litres per minute (BTPS) after ten weeks, for a group training two days per week, and after twenty weeks showed a further increase from 137.0 to 140.8 litres per minute (BTPS). The maximum pulmonary ventilation of a group which trained four times per week showed an increase from 138.9 to 140.2 litres per minute (BTPS) after ten weeks and a further increase from 140.2 to 142.6 litres per minute (BTPS) after twenty weeks of training.

Ribisl (77) reported a significant increase in maximal

pulmonary ventilation (129 to 143 litres per minute) after a five month training program.

Saltin et. al.(83) reported an increase in maximal pulmonary ventilation (129 to 156 litres per minute BTPS) after an eight week training program.

Saltin et. al.(85) trained forty-two subjects (aged 35 - 50) for eight to ten weeks. No significant decrease at submaximal loads were reported. However, there was an increase in maximal pulmonary ventilation of 15% (112.1 to 128.0 litres per minute BTPS).

Wenger (109) reported that maximum pulmonary ventilation was significantly greater in the two training groups compared to the control group after training, but the difference between the two training groups was not significant.

Evidence from the above studies indicate the pulmonary ventilation decreases at submaximal work loads, initial maximal work loads, and increases at maximum work loads due to training program of varying intensities and duration.

THE EFFECT OF TRAINING ON THE VENTILATORY EQUIVALENT

Saltin et. al.(83) did not obtain a significant change in the ventilatory coefficient after fifty-five days of training. He concluded that any increase in oxygen consumption at maximal loads was directly proportional to changes in pulmonary ventilation.

Saltin et. al.(85) confirmed the above results since the ratio of pulmonary ventilation to oxygen consumption remained unchanged both at maximal and submaximal work.

Wenger (109) found that the ventilatory equivalent at both the initial maximum load and the maximum load following training did not change. This substantiated the work of Saltin et. al.(83), and Saltin et. al.(85). This indicates that adaptations to the training stimulus occur in the circulatory system and/or metabolic processes and do not affect the pulmonary efficiency per se.

EFFECT OF TRAINING ON MAXIMUM WORK CAPACITY

Hanson et. al.(46) trained twenty-five men (aged 40 to 49 years) for one to one and a half hours per day, three days a week, for seven months. Following the training, the maximal work capacity improved 22% (from 868 to 1063 kpm per min.).

Massicotte (65) found significant increases in maximal work loads with training for the three training groups over the control group. However, no significant differences were found amongst the three training groups of children.

Seigel et. al.(87) trained nine blind men (aged 32 to 59 years) for fifteen weeks. The maximal work load increased 39% (from 626 to 790 kpm per minute) over the training program.

Wenger (109) reported that the work which produced maximum oxygen consumption was significantly greater for the two training groups compared to the control group following the training program. The T100 group also required a significantly greater work load than did the T60 group to produce $M\dot{V}O_2$ following the training.

The studies cited above indicate that greater work loads are required to produce maximal oxygen uptake after a training program.

EFFECT OF TRAINING ON BLOOD LACTATE

Brouha (15) found that the blood lactate levels at the initial maximum work load decreased significantly (105 to 80 Mg %) following a training program given to a group of college oarsmen.

Cunningham and Faulkner (26) trained eight males for six weeks in a program consisting of interval sprints and distance running. Blood lactate at maximal work increased 17% (101 to 119 mg %). An estimate of the maximum increase in blood lactate was obtained by subtracting the resting value for blood lactate 10 mg % from the maximum post-exercise blood lactate.

Costill (22) examined highly trained distance runners to determine the changes in blood lactate during prolonged, exhaustive running at varied intensities and durations. When the oxygen requirement of the run was less than 70% of the runner's aerobic capacity, little or no increase in blood lactate was observed. During two hours of running that required between 55 - 67% of maximal oxygen consumption, a very slight increase in lactic acid was found. Highly trained distance runners were found capable of utilizing more than 90% of maximal oxygen uptake (70 ml per kg per min.) for 25 - 30 minutes with only moderate accumulation of blood lactate.

Ekblom et. al.(37) reported that blood lactate levels decreased at the initial maximum work load (12.9 to 9.5 m M), and increased at the new maximum work loads (12.9 to 13.6 m M) following a training program. They reported total blood lactate levels.

Massicotte (65) reported that blood lactate concentration

decreased only in the first training group at a submaximal work load. Maximal blood lactate concentration only increased significantly, also, in the first training group after training.

Robinson and Harmon (78) trained nine sedentary students (aged 18 - 22 years) four days per week for six months. The training program consisted of over distance running combined with pace and speed work. They reported an increase in blood lactate (13 to 17.9 m M) at maximal work and a decrease in blood lactate concentration at the previous maximal work load (13.7 to 9 m M) as a result of the training.

Saltin et. al.(83) reported that their eight to ten week training program resulted in a decrease in blood lactate levels (6.3 to 4.7 m M) at a submaximal work load and an increase (12.8 to 14.0 m M) at maximal levels.

Wenger (109) reported that the blood lactate concentrations for the two training groups were significantly lower than the control after training at the initial maximum work load. The difference between the two training groups was not significant. Blood lactate concentrations at the new maximum oxygen consumptions were higher in the two training groups than in the control following training but this difference was not significant.

Williams et. al.(111) trained thirteen Bantu male subjects in an effort to determine the changes both in the maximum oxygen intake and in the level of oxygen intake at which anaerobic metabolism (excess lactate is used) starts in individuals before and after a regime of training on a bicycle ergometer during which

the men worked at both aerobic and anaerobic levels of effort. They reported that in untrained individuals the onset of anaerobic metabolism occurred at 40 - 45% of the maximum oxygen intake, in trained individuals at 55 - 60%, and in the exceptionally well trained men at about 70%.

There is general agreement on the effect of training on blood lactate levels. Training decreases blood lactate concentrations at submaximal work loads, and the initial maximum work loads, and increases the ability of the human organism to tolerate higher blood lactate levels at maximum work loads.

CHAPTER III

METHODS AND PROCEDURES

Thirty-six male volunteer subjects from the Edmonton City Police Department were used in the study. The age range of the subjects was 30 to 45 with the mean age being 37.4 years. The mean body weight was 88.65 kg before the training and 88.12 kg after the training.

The subjects came to the research laboratories in the Faculty of Physical Education at the University of Alberta to be tested the week prior to the start of the training program. They were then tested again at the same time of day during the week following the eight week training program.

The test gases used in the calibration of the metabolic equipment were checked with a Micro Scholander apparatus prior to both testing sessions according to the modified Scholander technique of Taylor (102). Both the Beckman E-2 oxygen analyzer, and the Godart Capnograph CO_2 analyzer were then carefully calibrated with the test gases prior to use each day, and at regular intervals during the testing sessions. The correction factor for converting the gas volume to STPD was taken three times per day during each testing day.

A Collins triple J valve was connected to a lightweight aluminum headgear, and fitted with a sterilized rubber mouthpiece for easy attachment to the subject. A lightweight, low-resistant, flexicoil, plastic hose was attached to the "out" vent on the J valve, and coupled to a Douglas Bag. The subject's nose was clamped

with a rubber clip. Expired air was collected at the desired time in the Douglas Bag and analysed later for oxygen content with a Beckman E-2 oxygen analyzer and for carbon dioxide with a Godart Capnograph. A Parkinson Cowan volume meter was used to measure the volume of expired air. An Olivetti 101 desk computer was pre-programmed with a program from Wenger (109) with the input data consisting of:

a) correction factor to STPD;

b) volume of gas expired (BTPS) litres per minute;

c) body weight in pounds;

d) Beckman E-2 oxygen analyzer reading;

e) % concentration of carbon dioxide in expired air obtained from the Godart Capnograph;

and which gave an output consisting of the following parameters:

a) % oxygen in expired air;

b) volumes of expired air (litres per minute STPD);

c) % nitrogen in expired air;

d) volume of inspired air (litres per minute STPD);

e) oxygen consumption (litres per minute STPD);

f) oxygen consumption (ml per kg per minute).

A maximum oxygen consumption test was performed according to the method of Astrand (3) as modified by Macnab, Conger, and Taylor (61). Expired air was collected and heart rates recorded during the fourth minute of work at each work load. Each subject exercised at a work load of 900 kpm , 1350 kpm , and the work load necessary to produce the maximal oxygen uptake.

In the test following the eight week program, the training subjects pedalled at work loads of 900 kpm , and the maximum work load which was attained at the initial test, and then further increases up to their new maximum work loads. The control subjects, however, worked at loads of 900 kpm , and their initial maximum work load unless their $M\dot{V}O_2$ had not plateaued.

Blood samples were taken by a registered medical technician from the brachial vein, fifteen to thirty seconds following each work load. The protein was precipitated with perchloric acid and then the serum analyzed for lactate concentrations via the enzymatic method described in the Sigma Technical Bulletin (98). A summary of this bulletin is given in appendix B.

ASSIGNMENT OF SUBJECTS TO THE TRAINING PROGRAMS

After the initial test all subjects were ranked according to their $M\dot{V}O_2$ in ml per kg per minute. They were then divided into three blocks of twelve subjects.

The block means for their maximum oxygen consumption in ml per kg per minute were:

B_1 = low fitness group (29.57 ml per kg per min.)

B_2 = middle fitness group (34.86 ml per kg per min.)

B_3 = high fitness group (41.09 ml per kg per min.)

The twelve subjects within each block were then randomly assigned to one of the three treatment groups:

a) training group one (T70) to train at 70% of their pre-training maximum oxygen consumption;

b) training group two (T50) to train at 50% of their

pre-training maximum oxygen consumption;

c) control group (TC) who were asked to maintain their normal living habits during the training period.

Thus there were twelve subjects in each of the treatment groups consisting of four subjects in each of the three blocks. (See table 1.) The group means for their maximum oxygen consumption in ml per kg per minute were:

TABLE 1

Experimental Design

Treatment Groups	Blocks (Initial Fitness Levels)	Time (Pre and Post-Training)
A_1 (N = 12) T70 (70% $M\dot{V}O_2$)	B_1 (n = 4) B_2 (n = 4) B3 (n = 4)	C_1 (Pre) C_2 (Post)
A_2 (N = 12) T50 (50% $M\dot{V}O_2$)	B_1 (n = 4) B_2 (n = 4) B_3 (n = 4)	
A_3 (N = 12) TC (Control	B_1 (n = 4) B_2 (n = 4) B_3 (n = 4)	

a) T70 - 35.19 ml per kg per minute;

b) T50 - 35.28 ml per kg per minute;

c) C - 35.03 ml per kg per minute.

TRAINING PROGRAM

Training was performed on Monarch bicycle ergometers three times per week for eight weeks. One group T70 worked at a work load equivalent to 70% of their measured aerobic capacity while the second training group worked at 50% of the aerobic capacity. Both groups worked until their oxygen cost in ml per kg per time were equal.

In order to estimate the oxygen cost of a work load performed on a bicyle ergometer by a subject, it was necessary to make a finer calibration of the bicycles (see Table 2), and to devise an oxygen consumption chart (see Table 3) based on Astrand-Rhyming Nomogram.

It was also necessary to find the subject who could perform the shortest time working at 50% or 70% of his $M\dot{V}O_2$ (depending on the training group he was assigned to) in order to equate the oxygen cost between the two training groups. Subject two from the low $M\dot{V}O_2$ block (B_1) in treatment one (T70) was the poorest performer on the bicycle ergometer at the start of the training program, lasting only nine minutes at his particular work load which produced an oxygen uptake equal to 70% of his $M\dot{V}O_2$. Thus, the total oxygen cost in ml per kg per time was based on this subject.

As subject two increased his performance time, and therefore, his total oxygen expenditure, the other subjects' oxygen expenditures were increased by increasing their performance times. Improvements in $M\dot{V}O_2$ were estimated once a week by using the Astrand - Rhyming

TABLE 2

Calibration of the Bicycle Ergometers

W. L. Kgm./minute	K. P. Calibration*
400	1.33
450	1.50
500	1.66
550	1.83
600	2.00
650	2.17
700	2.33
750	2.50
800	2.66
850	2.83
900	3.00
950	3.17
1000	3.33
1050	3.50
1100	3.66
1150	3.83
1200	4.00
1250	4.17
1300	4.33

*Based on 50 revolutions/minute and 1 revolution = 6 meters

TABLE 3

Total Oxygen Consumed in Litres/Minute

Working on a Bicycle Ergometer (9)

Kp	Revolutions 50	51	52	53	54
1.50	1.10	1.13	1.16	1.18	1.20
1.66	1.22	1.25	1.27	1.29	1.31
1.83	1.34	1.36	1.38	1.40	1.43
2.00	1.45	1.47	1.49	1.52	1.54
2.17	1.56	1.58	1.61	1.64	1.66
2.33	1.68	1.70	1.72	1.74	1.76
2.50	1.79	1.81	1.84	1.86	1.88
2.66	1.90	1.93	1.95	1.97	2.00
2.83	2.02	2.05	2.07	2.09	2.11
3.00	2.14	2.16	2.18	2.20	2.23
3.17	2.25	2.27	2.29	2.32	2.34
3.33	2.37	2.39	2.41	2.43	2.45
3.50	2.48	2.51	2.53	2.55	2.57
3.66	2.59	2.62	2.64	2.66	2.68
3.83	2.71	2.73	2.75	2.78	2.80
4.00	2.82	2.85	2.87	2.89	2.92
4.17	2.94	2.97	2.99	3.01	3.04
4.33	3.06	3.08	3.10	3.12	3.14

Nomogram. Work loads plus performance times were adjusted accordingly with the increases in estimated maximal oxygen uptake in order to enable all subjects to continue working at either 50% or 70% of their maximal oxygen uptakes. An age factor (8) was used for correction of predicted maximal oxygen uptake.

Each subject's work load and length of time for a training session was calculated as follows:

a) 50% or 70% of the initial $M\dot{V}O_2$ in ml per kg per min. (depending on training group) was divided into the gross oxygen cost in ml per kg per time of subject two ($M\dot{V}O_2$ 70 ml per kg per min. X time in minutes). This gave the desired training time for each subject.

b) 50% or 70% of the initial $M\dot{V}O_2$ in litres per minute gave the revolutions per minute and the tension (kp) from Table 3 deduced from the Astrand - Rhyming Nomogram. In order to allow individual subjects to work at either 50% or 70% of their maximum aerobic capacities, heart rates were monitored once per week, improvements in $M\dot{V}O_2$ were estimated with the use of the Nomogram, and work loads and performance times were then adjusted accordingly. In each training session and for the entire training program, the estimated gross oxygen cost in ml per kg per minute was the same for both experimental groups.

STATISTICAL PROCEDURES AND EXPERIMENTAL DESIGN

The experimental design (for diagrammatical display see Table 1) utilized was a 3 X 3 X 2 factorial design (fixed model)

with repeated measure on factor C (113). The three levels of factor A (treatments) were:

a) A_1 - 70% $M\dot{V}O_2$ X time

b) A_2 - 50% $M\dot{V}O_2$ X time

c) A_3 - control

so that 70% $M\dot{V}O_2$ X time = 50% $M\dot{V}O_2$ X time.

The three levels of factor B (initial fitness levels) were the three blocks into which the subjects had been assigned according to their initial $M\dot{V}O_2$ scores in ml per kg per minute. They were:

a) B_1 - low $M\dot{V}O_2$ scores

b) B_2 - medium $M\dot{V}O_2$ scores

c) B_3 - high $M\dot{V}O_2$ scores.

The two levels of factor C were :

a) C_1 - pre-training test scores

b) C_2 - post-training test scores

The data on each parameter was analyzed by a three way analysis of variance with repeated measures as discussed by Winer (113). If significant F ratios were obtained, the data was plotted and a decision made on which simple main effects were to be tested. Where F ratios for simple main effects were significant, a Newman-Keuls test was used as a comparison between means (113). The groups were equated on maximal oxygen consumption relative to body weight and not on all parameters, if F ratios for simple main effects were

significant at the pre-training test, a Scheffe Contrast test (113) was used between mean differences (pre-training values - post training values) to determine in each group if the improvements with training were significant. All computations were done via the IBM 360 computer at the University of Alberta.

The analysis of the data was divided into three distinct categories. All three involving a comparison of pre vs post training data.

1. A comparison of data at a fixed submaximal work load (900 kpm).
2. A comparison of data from the initial maximal work load with data from that same work load after the training period. Thus the post training work load is submaximal.
3. A comparison of data from the initial maximal work load with data from the post training maximal work load.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AT SUBMAXIMAL WORK LOAD (900 Kpm/min.)

The pre and post training values on the various parameters are tabulated in Table 4 (mean $\pm$ S.D.). The statistical analysis of each parameter is summarized in Appendix F.

HEART RATE (H R)

The H R at the submaximal work load (900 Kpm/min.) showed a decrease after the eight week training program. Although the T70 and T50 groups decreased 16.9 and 18.9 beats per minute respectively (see Figure 1), statistically this decrease was not significantly different from the control group. The three way ANOVA (Appendix F-1,A) revealed significant (p.001) time main effects and a significant (p.001) treatment X time interaction. However, a one way ANOVA to test the simple main effects at the post training test was not significant so a statistical comparison of the means was not warranted.

OXYGEN CONSUMPTION ($\dot{V}O_2$)

There was no significant change in the gross oxygen consumption at the submaximal work load (see Figure 2). Both groups T70 and T50 showed very slight decreases (0.07 and 0.10 litres per minute respectively) while the oxygen consumption for C increased 0.03 litres per minute.

GROUP MEANS FOR VARIOUS PARAMETERS AT SUBMAXIMAL LOAD (900 Kpm)

AS OBTAINED AT PRE AND POST TRAINING TESTS

raining rogram	H R Beats/min		$\dot{V}O_2$ Litres/min		$\dot{V}O_2$ ml/kg/min		$\dot{V}E$ litres/min		HLa mg %		$\dot{V}E/\dot{V}O_2$		O_2 Pulse ml/beat	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
70 ean $\pm$ S.D. n=12)	141.7 $\pm$ 15.6	124.8 $\pm$ 14.6	1.93 $\pm$ 0.22	1.86 $\pm$ 0.20	21.83 $\pm$ 3.48	20.91 $\pm$ 2.24	44.82 $\pm$ 6.52	42.63 $\pm$ 6.13	22.00 $\pm$ 8.71	17.42 $\pm$ 6.02	25.63 $\pm$ 8.49	22.99 $\pm$ 2.81	13.83 $\pm$ 2.63	15.11 $\pm$ 2.69
50 ean $\pm$ S.D. n=12)	147.7 $\pm$ 11.8	128.8 $\pm$ 12.8	2.07 $\pm$ 0.13	1.97 $\pm$ 0.23	23.22 $\pm$ 1.97	22.24 $\pm$ 2.40	48.07 $\pm$ 7.44	45.27 $\pm$ 6.38	25.67 $\pm$ 7.89	19.42 $\pm$ 3.40	23.33 $\pm$ 3.93	23.03 $\pm$ 2.33	13.87 $\pm$ 1.82	15.39 $\pm$ 2.05
ean $\pm$ S.D. n=12)	140.6 $\pm$ 15.0	139.31 $\pm$ 16.4	1.88 $\pm$ 0.25	1.91 $\pm$ 0.17	21.81 $\pm$ 3.66	22.22 $\pm$ 2.74	44.58 $\pm$ 5.58	47.09 $\pm$ 8.73	26.58 $\pm$ 9.47	25.58 $\pm$ 9.79	23.96 $\pm$ 3.23	24.70 $\pm$ 4.38	13.52 $\pm$ 2.22	13.86 $\pm$ 1.76

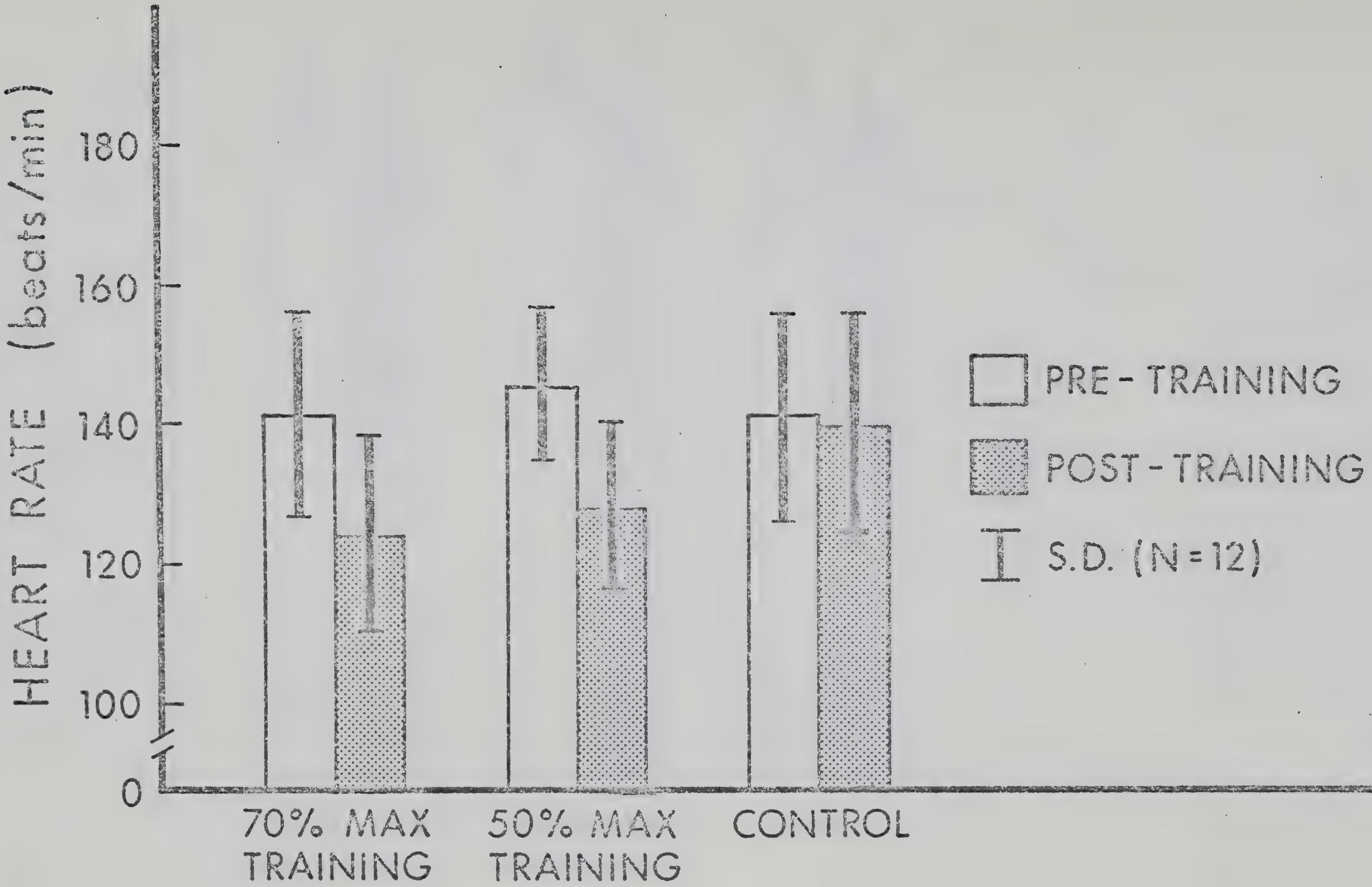

FIGURE 1 - HEART RATE AT SUBMAXIMAL WORKLOAD

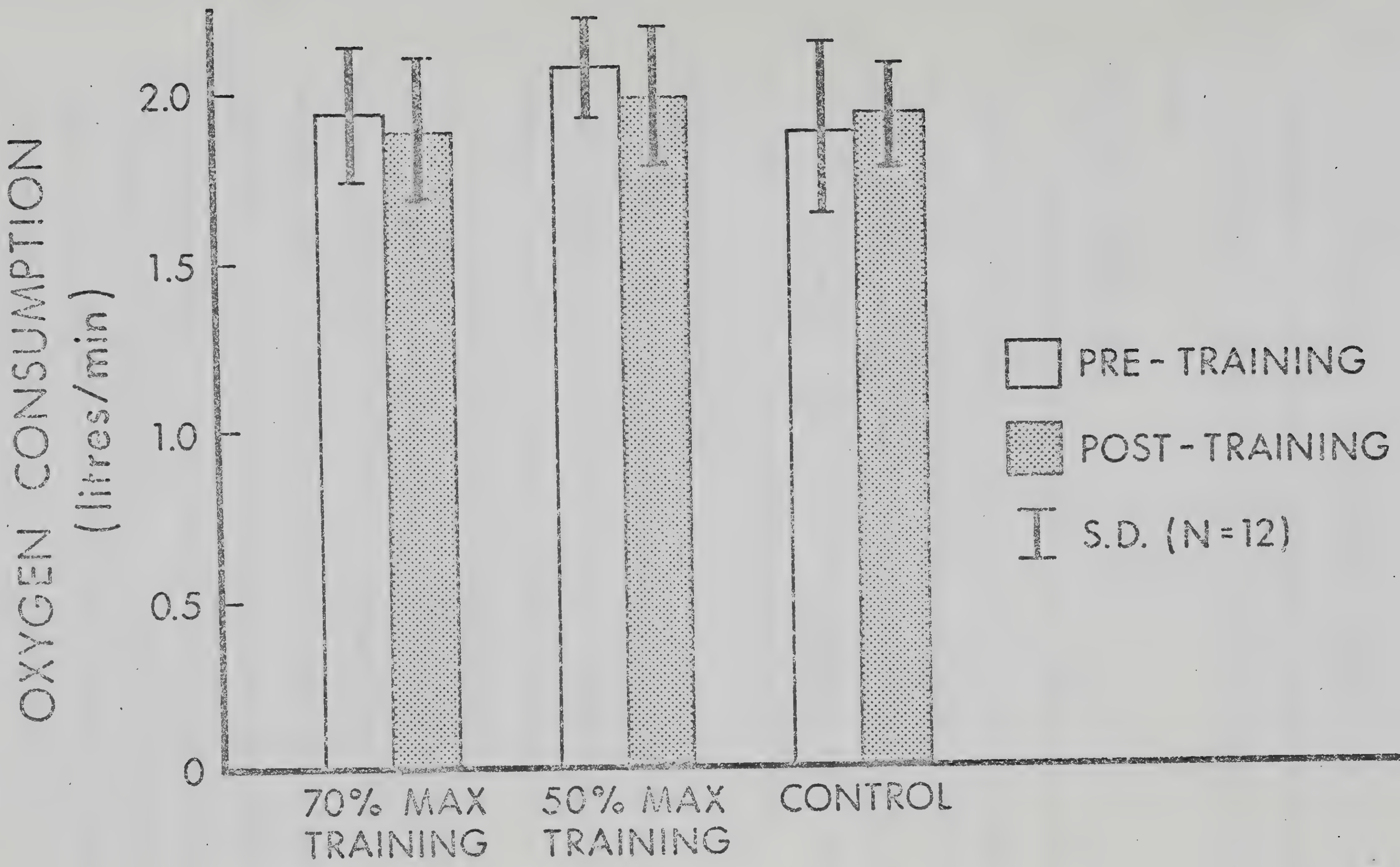

FIGURE 2 - OXYGEN CONSUMPTION AT SUBMAXIMAL WORK LOAD

There was also no significant change in the $\dot{V}O_2$ relative to body weight. Both groups T70 and T50, did decrease slightly (0.92 and 0.98 ml/kg/min.) while C increased slightly (0.41 ml/kg/min.).

PULMONARY VENTILATION

The pulmonary ventilation at the submaximal work load (900 Kpm/min.) decreased slightly in the T70 and T50 groups (2.19 and 2.80 litres per min. respectively) while the C group increased by 2.51 litres per min. over the eight week training program (Table 4). However a three way ANOVA (Appendix F-IV) failed to show any significant treatment of interaction effects.

BLOOD LACTATE CONCENTRATION

All groups T70, T50 and C showed decreased in blood lactate concentrations (4.68, 6.25 and 1.00 mg % respectively) at the submaximal work load following the eight week program.

Although the groups were equated on aerobic power after the pre-training test, they were not similar in the degree to which the anaerobic energy processes were engaged. The three way ANOVA (appendix F-V,A) revealed that the treatments X time interaction was significant. After plotting the means of the three treatment groups for the pre and post training tests (Figure 3), two separate one way ANOVA to determine the simple main effects at both the pre and post training tests were performed. The analysis of variance for all the treatments at the pre training test revealed an insignificant F ratio ($p \leqslant .05$). The one way ANOVA (Appendix F-V,B) to test the simple main effects of the three treatments at the post training

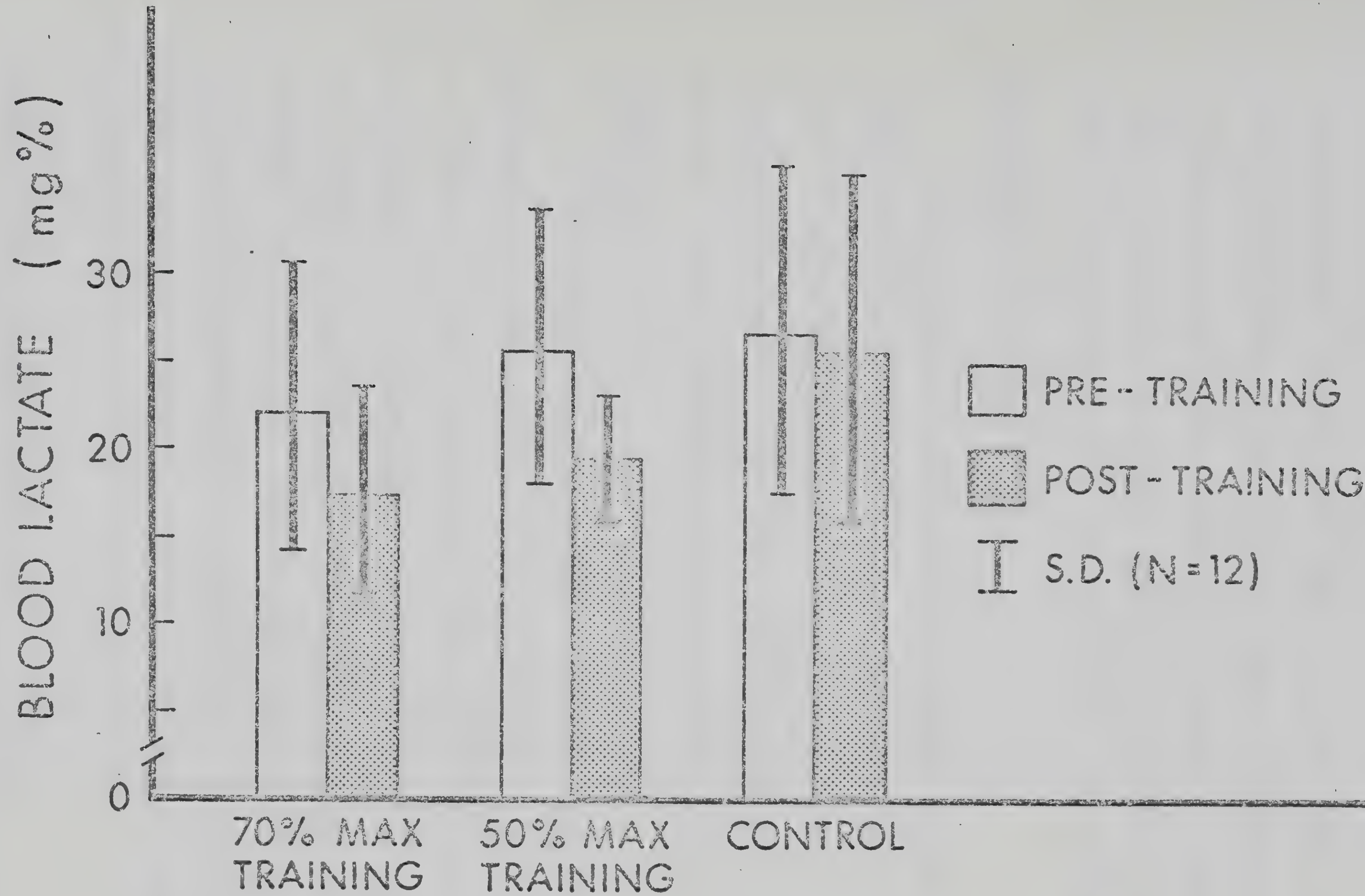

FIGURE 3 - BLOOD LACTATE CONCENTRATION AT SUBMAXIMAL WORK LOAD

test resulted in a significant F ratio ($p \leqslant .05$). The Newman-Keuls test then showed that the blood lactate concentration of the two training groups at the submaximal work load was signifcantly ($p \leqslant .05$) lower than the control group. (Appendix F-V,C) but there was no difference between the means of the two training groups.

VENTILATORY EQUIVALENT ($\dot{V}E/\dot{V}O_2$)

The $\dot{V}E/\dot{V}O_2$ decreased in both training groups T70 and T50 (2.64 and 0.30 respectively) and increased in the control group (0.74). Neither the treatment (A) main effects nor the treatment X time (AC) interaction were significant (Appendix F-V1, A) so an attempt to analyze the simple main effects was not justified.

OXYGEN PULSE

The oxygen pulse (See Figure 4) did not show a significant increase at the submaximal work load as a result of the training even though the two training groups, T70 and T50 increased the millilitres of oxygen consumption per heart beat by 1.28 and 1.52 ml per beat respectively. The control group improved slightly by 0.34 ml per beat. The threeway ANOVA (Appendix F-V11,A) revealed no significant treatment (A) main effects nor treatment X time (AC) interaction, so an attempt to test the simple main effects was not justified.

RESULTS AT INITIAL MAXIMUM WORK LOAD

The pre and post training values for the various parameters are tabulated in Table 5 (mean $\pm$ S.D.). The statistical analysis of each parameter is summarized in Appendix G.

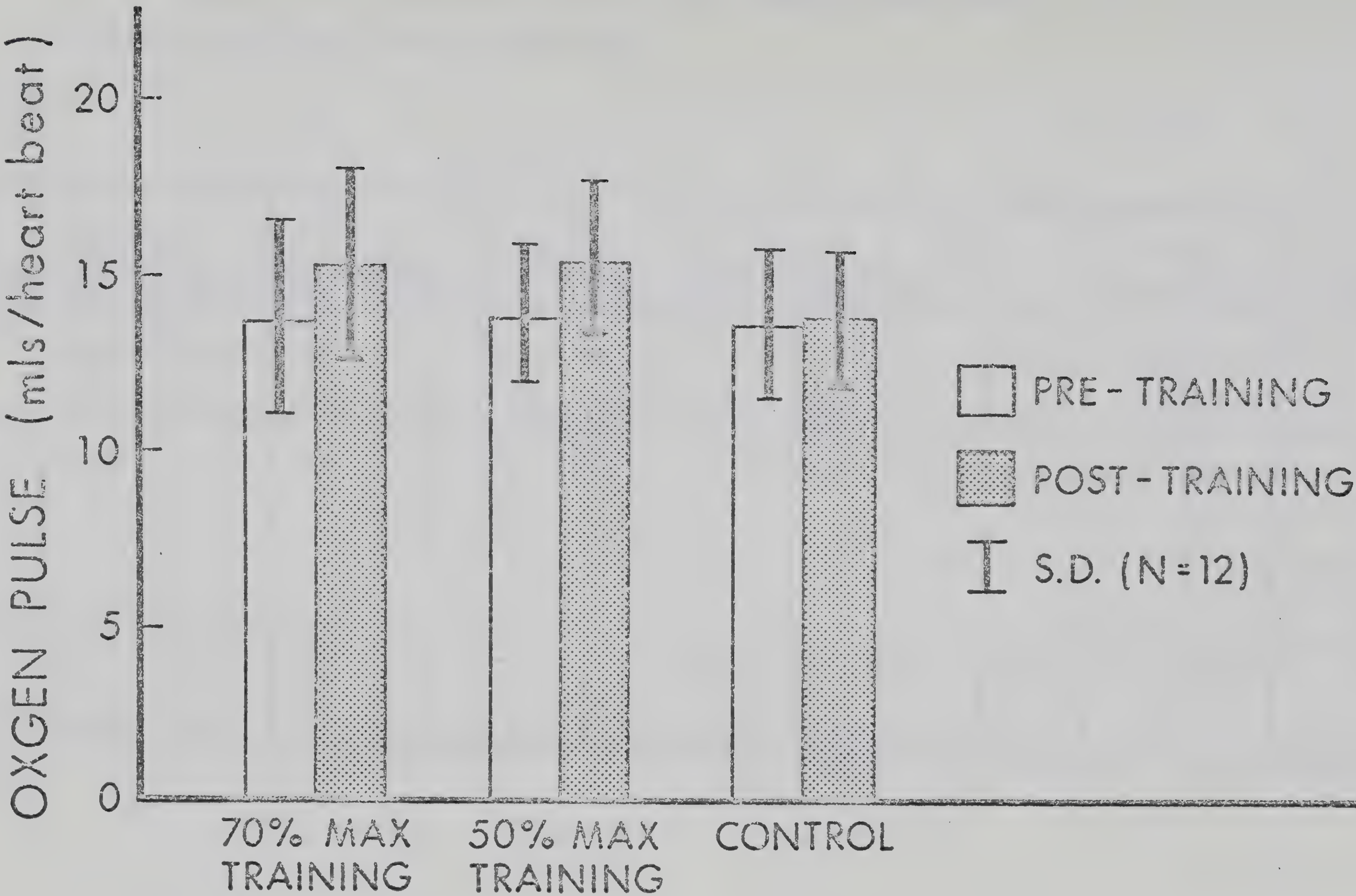

FIGURE 4 - OXYGEN PULSE AT SUBMAXIMAL WORK LOAD

GROUP MEANS FOR VARIOUS PARAMETERS AT INITIAL MAXIMAL WORK LOADS AS

OBTAINED AT PRE AND POST TRAINING TESTS

Training Program	Work Load Kpm/min.	H R Beats/min		$\dot{V}O_2$ Litres/min		$\dot{V}O_2$ ml/kg/min		$\dot{V}E$ Litres/min		HLa Mg%		$\dot{V}E/\dot{V}O_2$		O_2 Pulse ml/beat	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
T70 Mean ± S.D. (n=12)	1525 ± 210.52	184.42 ± 7.41	164.00 ± 11.43	3.17 ± 0.46	2.94 ± 0.42	35.20 ± 5.84	33.53 ± 5.37	87.48 ± 18.75	71.75 ± 14.43	79.67 ± 17.32	50.75 ± 14.41	27.70 ± 5.18	24.49 ± 4.25	17.20 ± 2.47	17.98 ± 2.62
T50 Mean ± S.D. (n=12)	1475 ± 190.09	181.17 ± 8.89	159.58 ± 5.63	3.14 ± 0.45	2.90 ± 0.42	35.28 ± 4.97	32.86 ± 3.91	93.77 ± 23.78	68.70 ± 18.96	82.33 ± 20.98	53.42 ± 16.83	29.57 ± 4.51	23.40 ± 3.68	17.40 ± 2.89	18.20 ± 2.78
C Mean ± S.D. (n=12)	1537.5 ± 293.97	182.50 ± 10.33	181.08 ± 8.76	3.03 ± 0.51	3.02 ± 0.47	35.03 ± 5.75	34.96 ± 5.75	93.87 ± 23.09	92.42 ± 21.93	100.08 ± 22.52	95.75 ± 15.66	30.81 ± 4.99	30.43 ± 4.63	16.70 ± 3.04	16.73 ± 2.91

WORK LOAD

The maximum work loads at the pre training test for the different groups were 1525 $\pm$ 210.52 Kpm per minute (T70), 1475 $\pm$ 190.09 Kpm per minute (T50), and 1537.5 $\pm$ 293.97 Kpm per minute (C).

HEART RATE

Following the training program, the heart rate at the initial maximum work load showed a large decrease for the two training groups as compared to the control group. The heart rates decreased 20.42 and 21.59 beats per minute for the T70 and T50 training groups respectively, while the control group decreased only 1.42 beats per minute (Table 5 and Figure 5). A three way ANOVA (Appendix G-1,A) showed significant treatment (A), time (C), and treatment X time (AC) effects. After plotting the means of the different training groups at the pre and post training test (Figure 2) it was decided to test for the simple main effects of the three treatments at post training. The one way ANOVA to test the simple main effects (Appendix G-1,B) revealed a significant (p.01) F ratio. The Newman-Keuls test showed that the heart rates after training of both T70 and T50 were significantly (p.01) lower than the control group (Appendix G-1,C) but there was no difference between the means of the two training groups.

OXYGEN CONSUMPTION

There was no significant change in the gross oxygen consumption at the initial maximum work load. All groups showed very slight decreases in oxygen consumption (0.23, 0.24, 0.01 litres per minute for T70, T50 and C respectively).

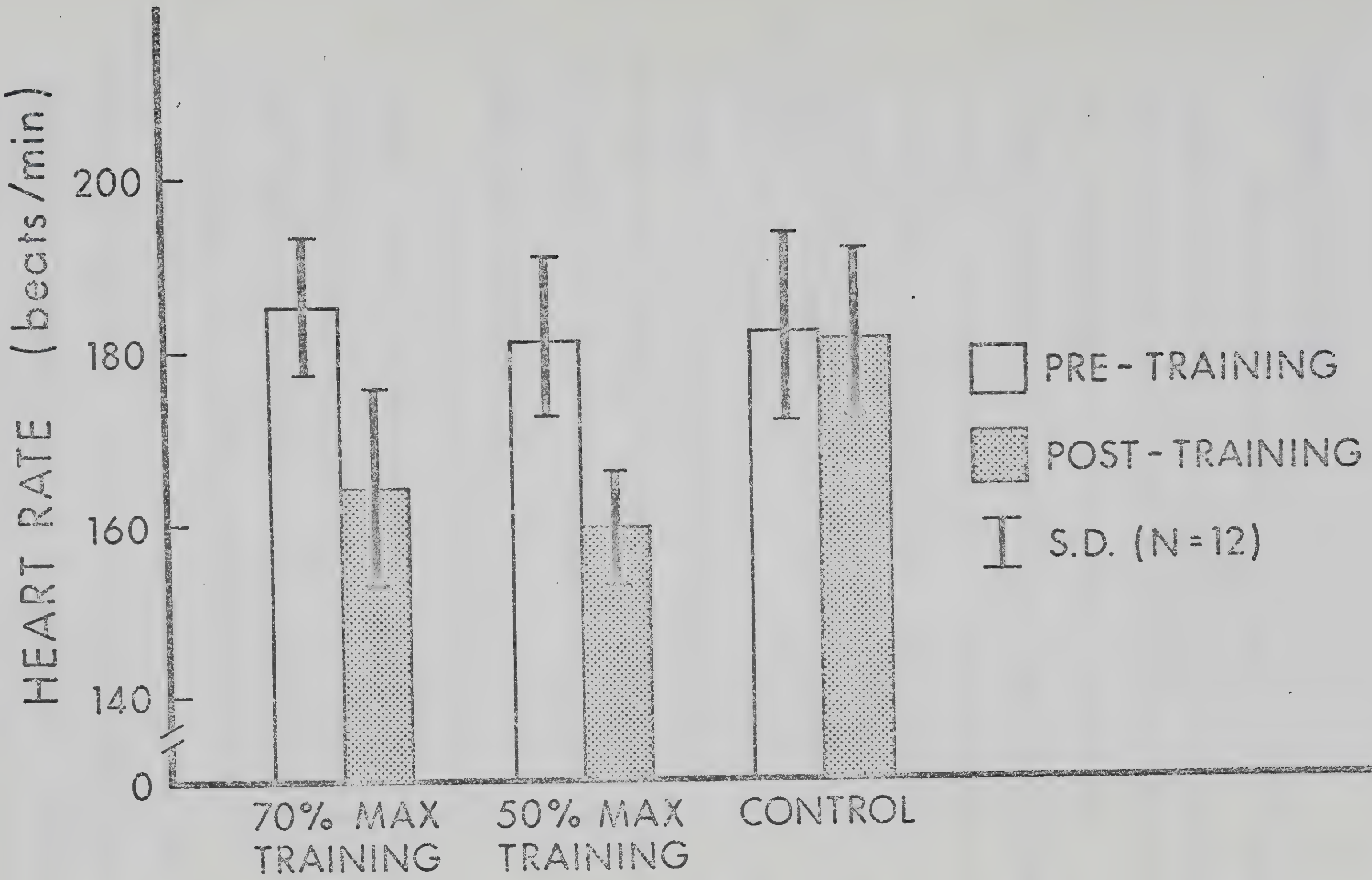

FIGURE 5 - HEART RATE AT INITIAL MAXIMAL WORK LOAD

PULMONARY VENTILATION ($\dot{V}E$)

Following the training prgram, the $\dot{V}E$ at the initial maximum work load showed a large decrease for the two training groups compared to the control group. The $\dot{V}E$ decreased 15.73, 25.07 and 1.45 litres per minute for T70, T50 and C respectively. A three way ANOVA (Appendix G-IV,A) showed significant time (C) and treatment X time (AC) effects. After plotting the means (Figure 6) it was decided to test for the simple main effects of the three treatments at post training. The one way ANOVA to test the simple main effects (Appendix G-IV,B) revealed a significant (p.01) F ratio. The Newman-Keuls test showed the pulmonary ventilation after training of both T70 and T50 were significantly (p.05) lower than the control group (Appendix G-IV,C) but there was no difference between the means of the two training groups.

BLOOD LACTATE CONCENTRATION

Both the T70 and T50 groups showed substantial decreases in blood lactate concentrations (28.92 and 28.91 mg % respectively) at the initial maximum work load at the post training test. The control group showed a slight decrease in the blood lactate concentration at the initial maximum load (4.33 mg %).

Although the groups were equated on aerobic power after the pre training test, they were not similar in blood lactate concentration at maximal work loads. (Figure 7). The three way ANOVA (Appendix G-V,A) showed that the treatment (A), time (C), and the treatments X time interaction (AC) were significant. After plotting the means of the three treatment groups for the pre and

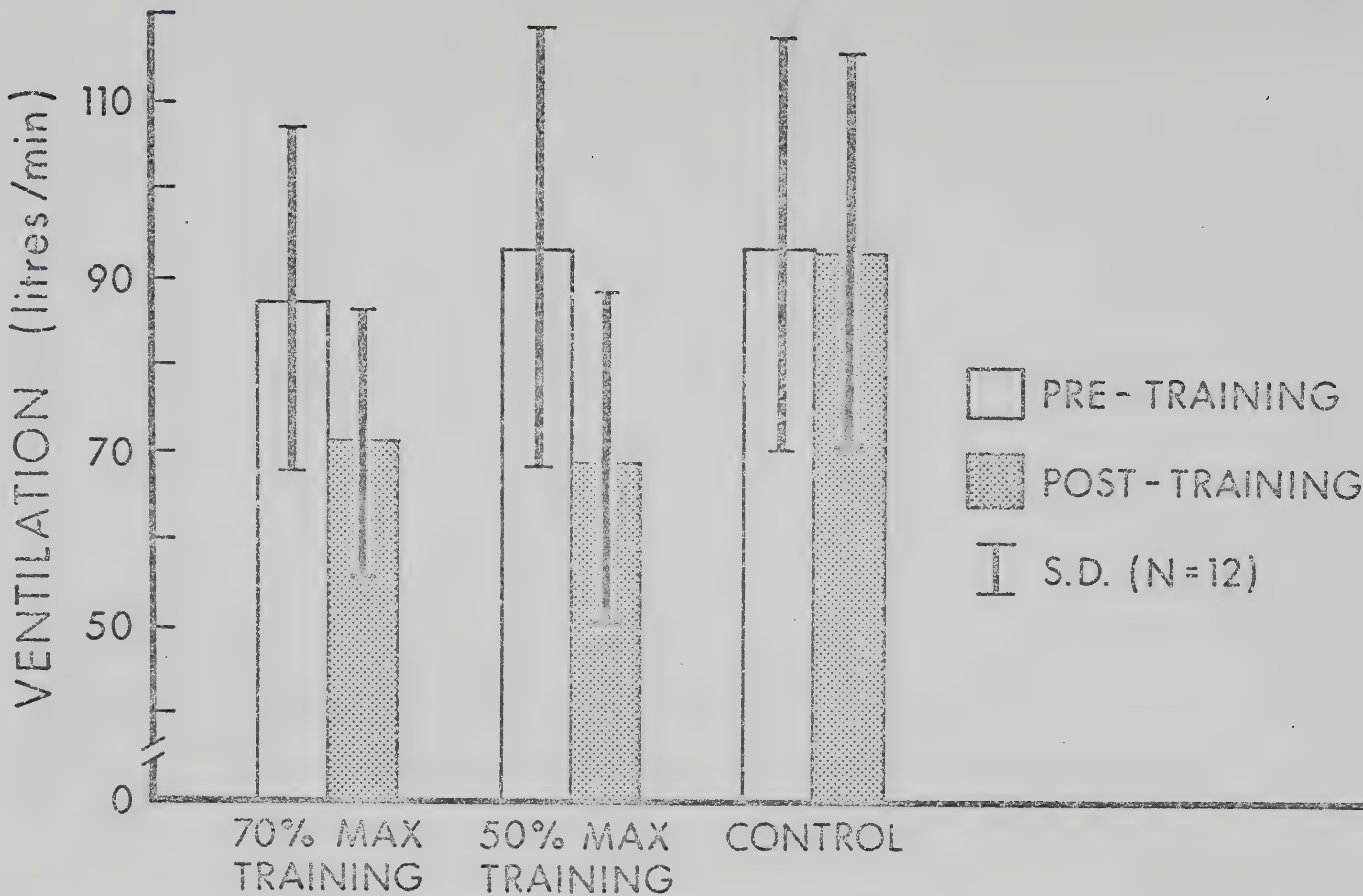

FIGURE 6 - MINUTE VENTILATION AT INITIAL MAXIMAL WORK LOAD

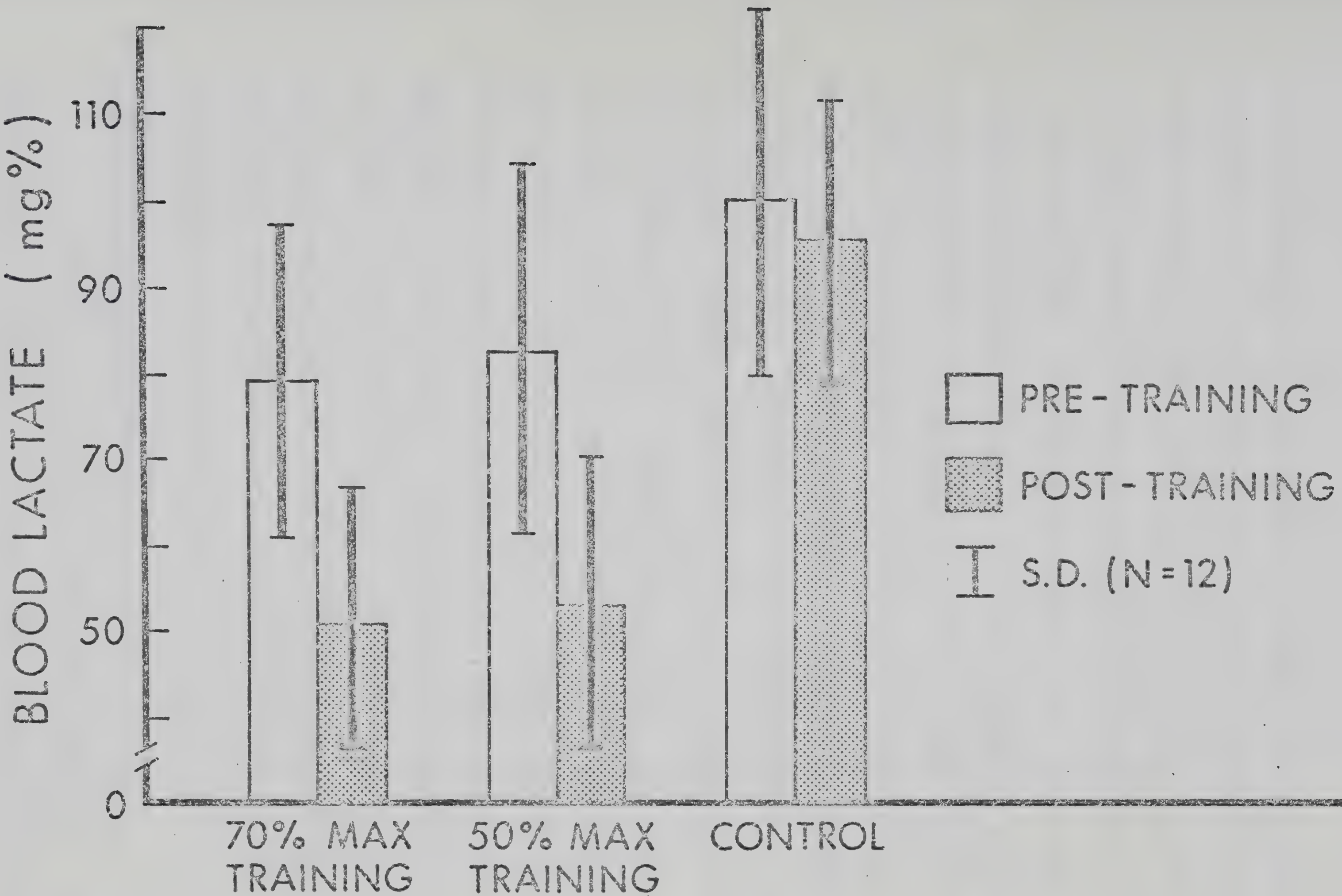

FIGURE 7 - BLOOD LACTATE CONCENTRATION AT INITIAL MAXIMUM LOAD

post training tests (Figure 7), two separate one way ANOVA to determine the simple main effects at the pre and post training tests were used. The analysis of variance (Appendix G-V,B) for all the treatments at the pre training test resulted in a significant F ratio ($p \leqslant .05$). The Newman-Keuls test then showed that the blood lactate concentration of the control group at the initial maximum work load was significantly (p.05) higher than the training groups. The one way ANOVA (Appendix G-V1,B) to test the simple main effects of the three treatments at the post training test also resulted in a significant F ratio ($p \leqslant .01$) but an inspection of the means revealed that the two training groups had decreased very substantially since the pre training test. The Newman-Keuls (Appendix V1,C) showed the blood lactate concentrations after training of both T70 and T50 were significantly (p.01) lower then the control group but there was no difference between the means of the two training groups. A Scheffe's contrast (Appendix G-V1,D) was done to see if the difference between the training groups and control group at the post training test were significantly greater then the difference between them on the pre training test. These differences were significant (p.01).

VENTILATORY EQUIVALENT ($\dot{V}E/\dot{V}O_2$)

Following the training program, the ventilatory equivalent at the initial maximum load showed quite a substantial decrease for the two training groups compared to the control group. The ventilatory equivalent decreased 3.21 and 6.17 for the T70 and T50 training groups respectively, while the control group decreased only 0.38.

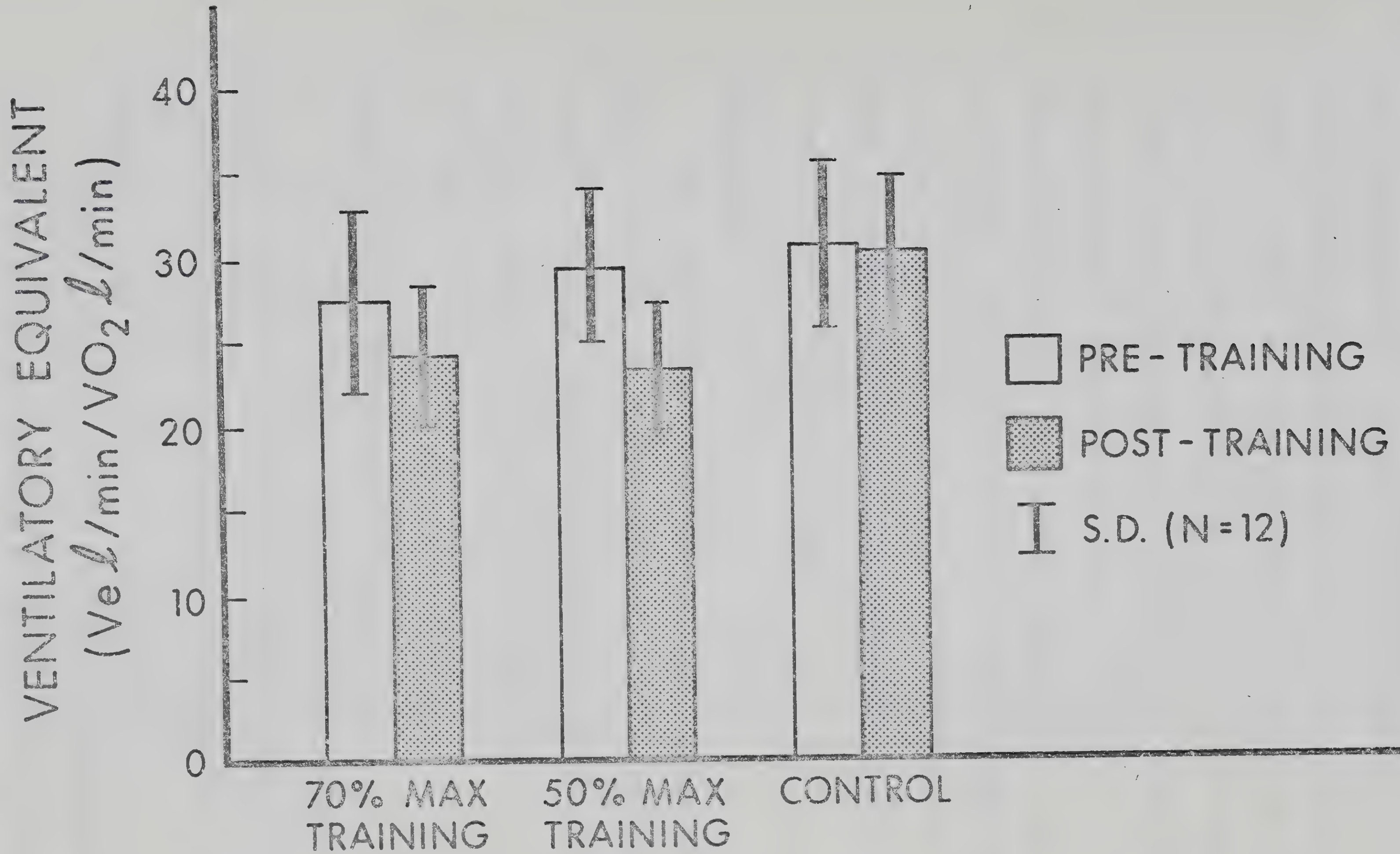

FIGURE 8 - VENTILATORY EQUIVALENT AT INITIAL MAXIMUM LOAD

(Table 5 and Figure 8.) A three way ANOVA (Appendix G-V11,A) revealed significant treatment (A), time (C), and treatment X time (AC) effects. After plotting the means (Figure 8) it was decided to test for simple main effects of the three treatments at post training. The one way ANOVA to test the simple main effects (Appendix G-V11,B) revealed a significant F ratio (p.01) and thus a Newman-Keuls test was carried out to see which, if any, means were different. The Newman-Keuls test showed the ventilatory equivalent after training significantly lower (p.01) than the control group (Appendix G-V11,C) but there was no difference between the means of the two training groups.

OXYGEN PULSE

The oxygen pulse did not show a significant improvement (Appendix G-V11) at the initial maximum work load as a result of training. All three groups increased the millilitres of oxygen uptake very slightly. (0.78, 0.80, and 0.03 ml/beat for T70, T50, and C respectively.

RESULTS AT MAXIMUM WORK LOADS

The pre and post training values on the various parameters at maximum work loads are tabulated in Table 6 (mean $\pm$ S.D.). The statistical analysis of each parameter is summarized in Appendix H.

WORK LOADS

The work load necessary to attain maximum oxygen consumption increased in the two training groups as a result of the training programs while the work load for the control group remained unchanged.

TABLE 6

GROUP MEANS FOR VARIOUS PARAMETERS AT MAXIMAL WORK LOADS AS

OBTAINED AT PRE AND POST TRAINING TESTS

raining rogram	Work Load Kpm/min		H R Beats/min		$\dot{M}VO2$ Litres/min		$\dot{M}VO2$ ml/kg/min		$\dot{M}VE$ Litres/min.		HLa Mg%		$\dot{M}VE/\dot{M}VO2$		02 Pulse ml/beat	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
70 ean ± S.D. n=12)	1525 ± 210.52	1887.5 ± 216.50	184.42 ± 7.40	182.08 ± 6.07	3.17 ± 0.46	3.42 ± 0.46	35.20 ± 5.84	38.53 ± 5.62	87.48 ± 18.75	92.57 ± 13.84	79.67 ± 17.32	91.83 ± 17.03	27.70 ± 5.18	27.35 ± 4.91	17.20 ± 2.47	18.89 ± 2.70
50 lean ± S.D. (n=12)	1475 ± 190.09	1762.5 ± 222.71	181.17 ± 8.89	180.25 ± 6.44	3.14 ± 0.45	3.48 ± 0.41	35.28 ± 4.97	39.34 ± 4.65	93.77 ± 23.78	98.70 ± 25.90	82.33 ± 20.89	92.17 ± 18.32	29.57 ± 4.52	27.96 ± 4.25	17.40 ± 2.89	19.35 ± 2.56
C lean ± S.D. (n=12)	1537.5 ± 293.97	1537.5 ± 293.97	182.50 ± 10.33	181.08 ± 8.76	3.03 ± 0.51	3.02 ± 0.47	35.03 ± 5.75	34.96 ± 5.75	93.87 ± 23.09	91.87 ± 22.88	100.08 ± 22.52	95.75 ± 15.66	30.81 ± 4.99	30.43 ± 4.63	16.70 ± 3.04	16.73 ± 2.91

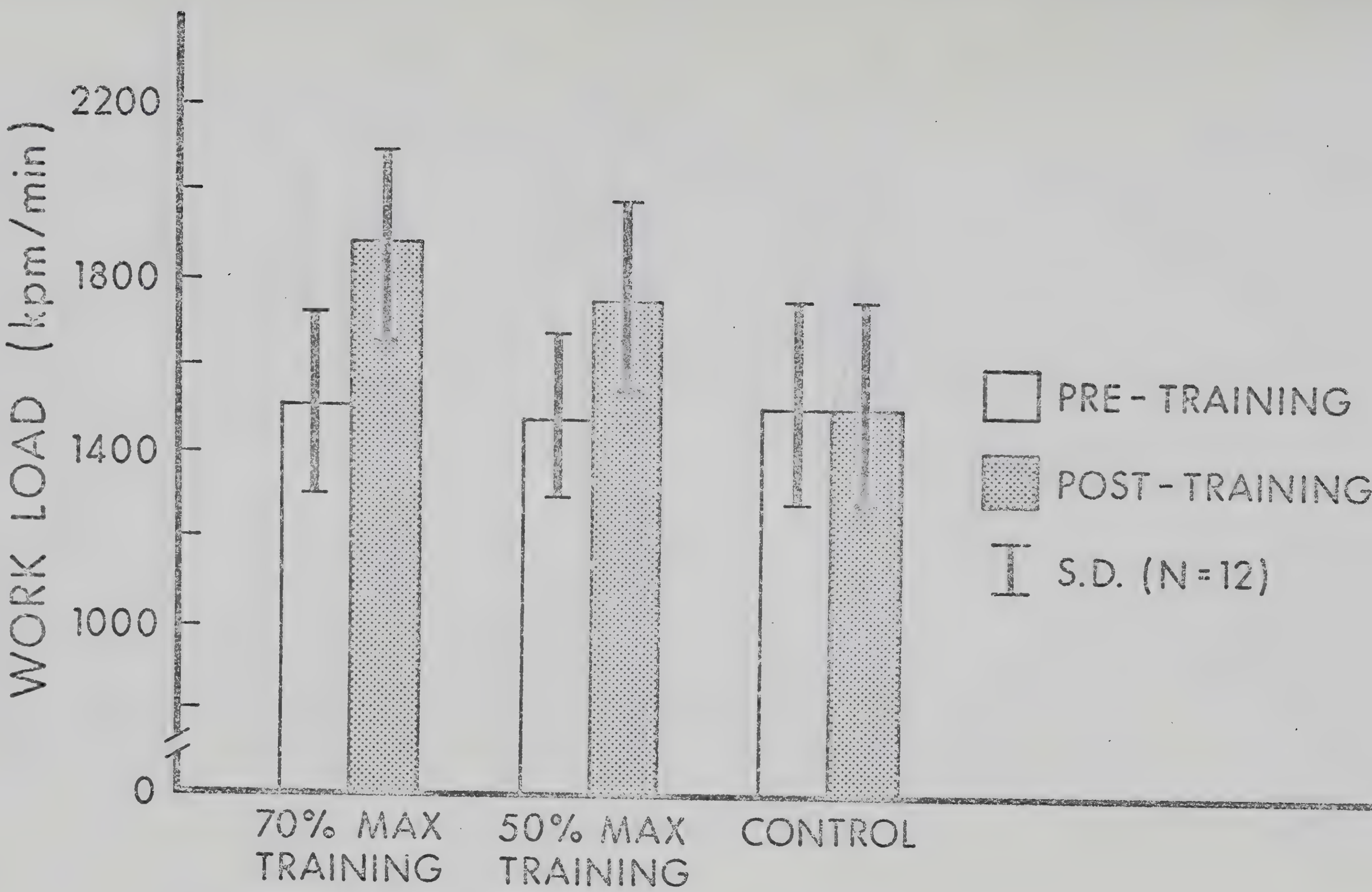

FIGURE 9 - WORK LOADS AT MAXIMAL OXYGEN CONSUMPTION

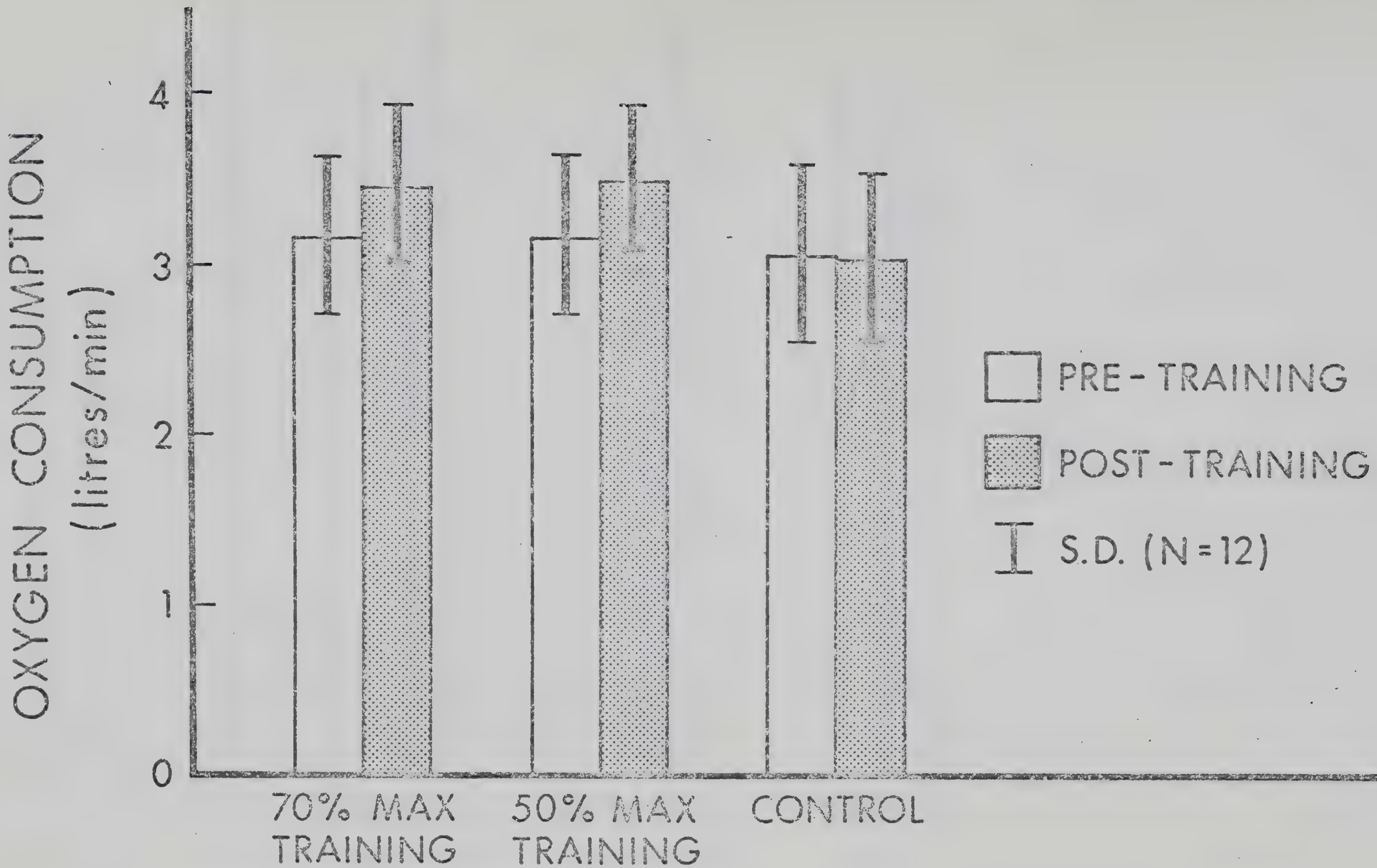

FIGURE 10 - MAXIMAL OXYGEN CONSUMPTION FOR THE DIFFERENT TRAINING GROUPS

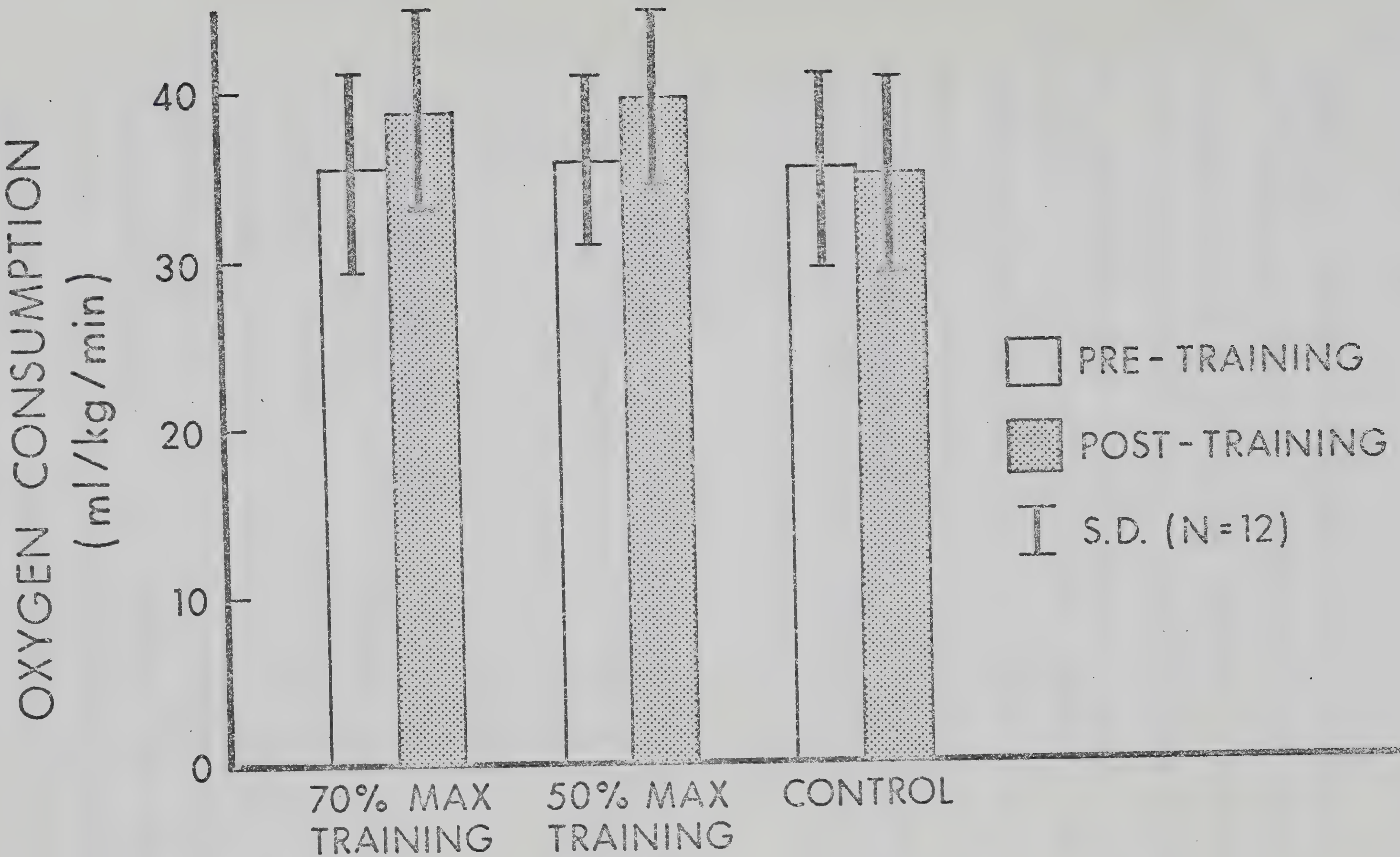

FIGURE 11 - MAXIMAL OXYGEN CONSUMPTION RELATIVE TO BODY WEIGHT FOR DIFFERENT TRAINING GROUPS

(Figure 9). The maximum work load increased 362.5 Kpm per minute for the T70 group and 287.5 Kpm per minute for the T50 group. The three way ANOVA (Appendix H-1,A) revealed significant time (C) and treatment X time (AC) effects. After plotting the means a one way ANOVA for simple main effects of all treatments at the post training test resulted in a significant (p.01) F ratio (Appendix H-1,B). A Newman-Keuls test (Appendix H-1,C) indicated that the T70 group required significantly (p.01) greater workloads than the control group to attain maximum oxygen consumption. The T50 group also required greater workloads (p.05) than the control group. There was no difference between the two training groups.

MAXIMUM HEART RATE

The heart rate at which maximum oxygen consumption was attained did not change significantly for any of the groups over the training program. The three way ANOVA revealed that none of the main effects or interaction effects were significant (Appendix H-11,A).

MAXIMUM OXYGEN CONSUMPTION ($M\dot{V}O_2$)

The gross oxygen consumption (litres per minute STPD) showed an increase of 0.25 and 0.34 litres per minute for the T70 and T50 training groups respectively (Figure 10). The control group decreased 0.01 litres per minute. The three way ANOVA (Appendix H-111,A) revealed significant time (C) and treatment X time (AC) effects ($p \leqslant .003$). A one way ANOVA to test for simple main effects (Appendix H-111,B) of the treatments at the post training test was significant ($p \leqslant .05$). The Newman-Keuls test (Appendix H-111,C) showed both training groups to be significantly higher ($p \leqslant .05$) on

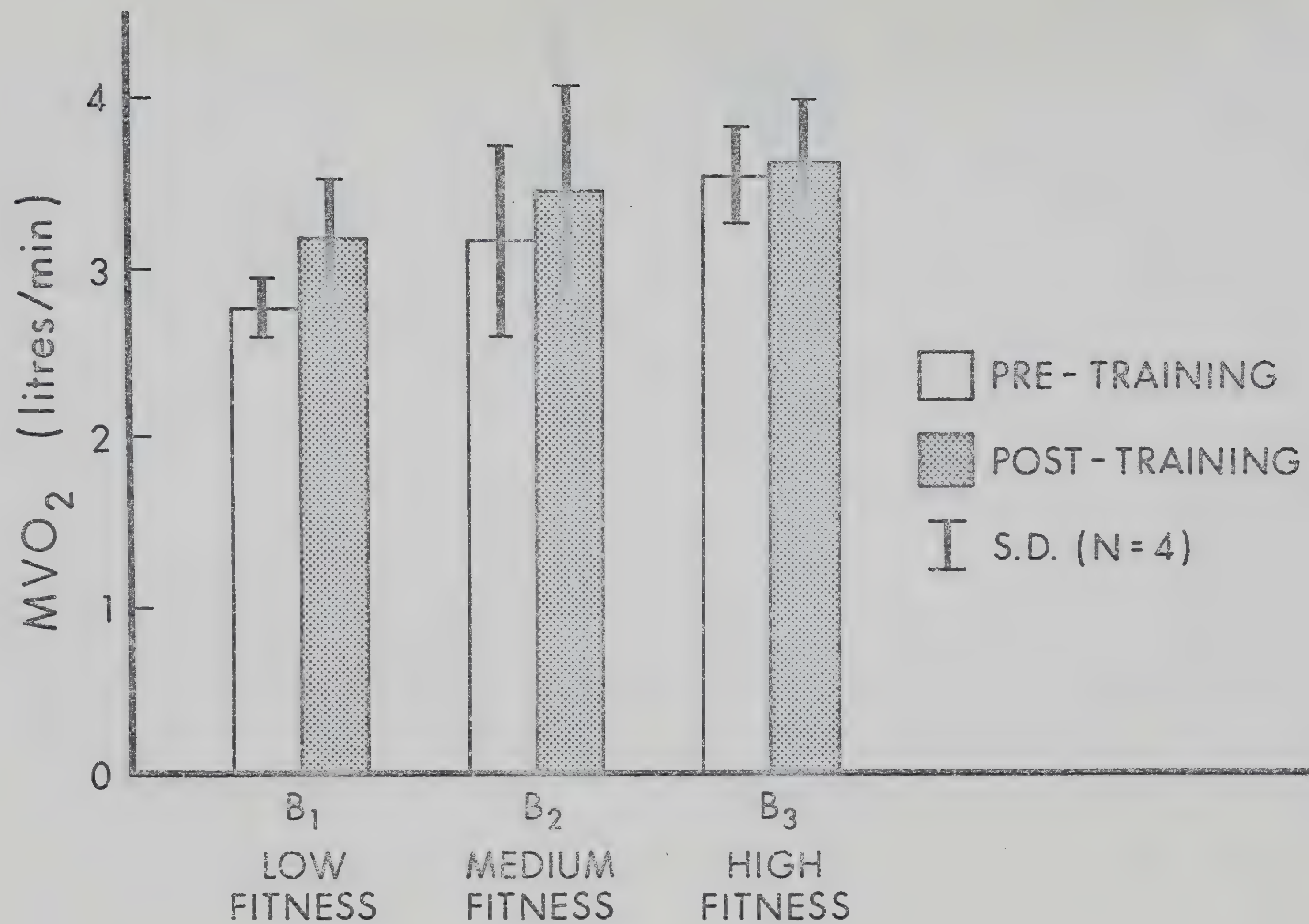

FIGURE 12 - $M\dot{V}O_2$ (litres/min) FOR BLOCKS IN GROUP T70

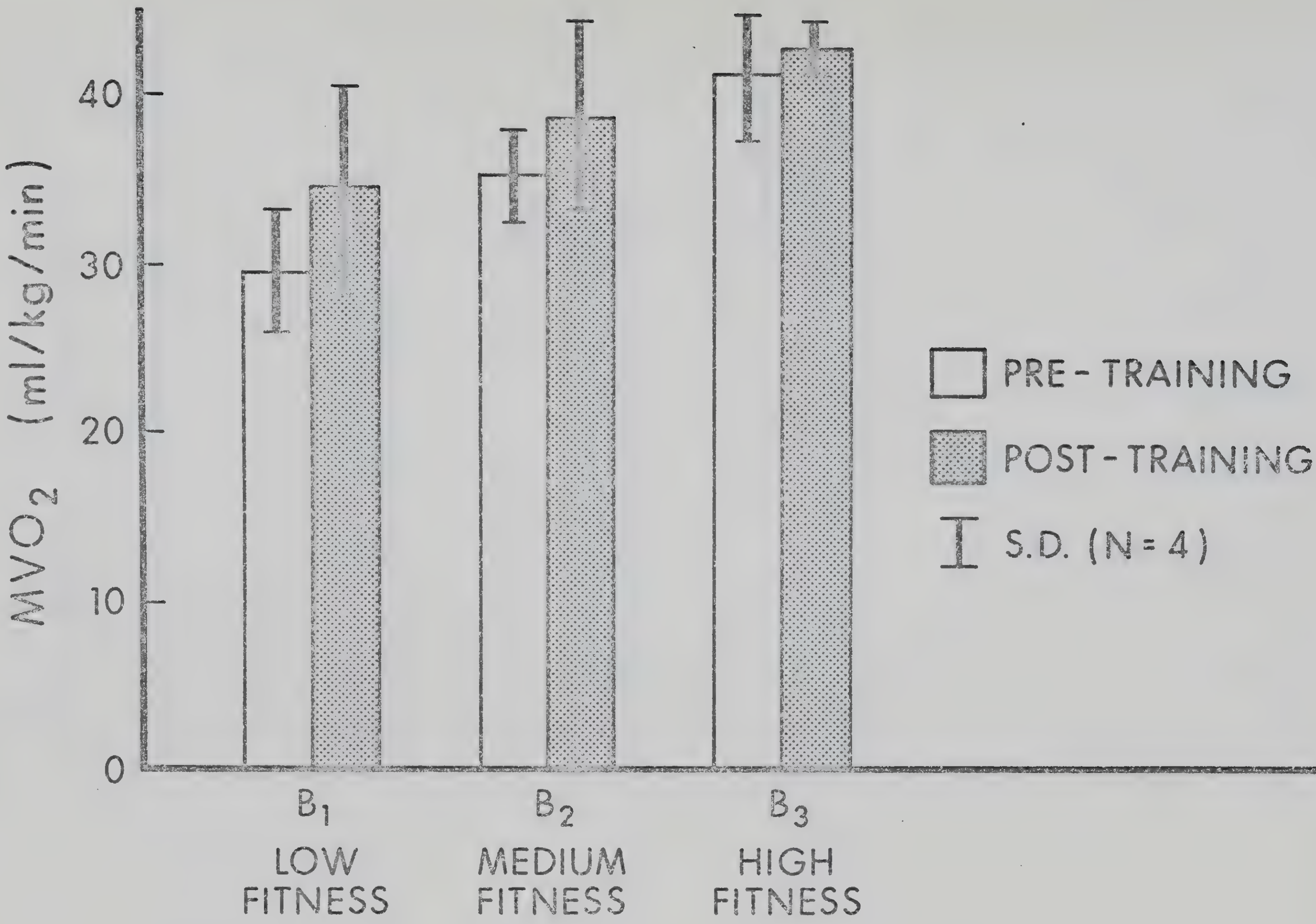

FIGURE 13 - $\dot{M}VO_2$ (ml/kg/min) FOR BLOCKS IN GROUP T70

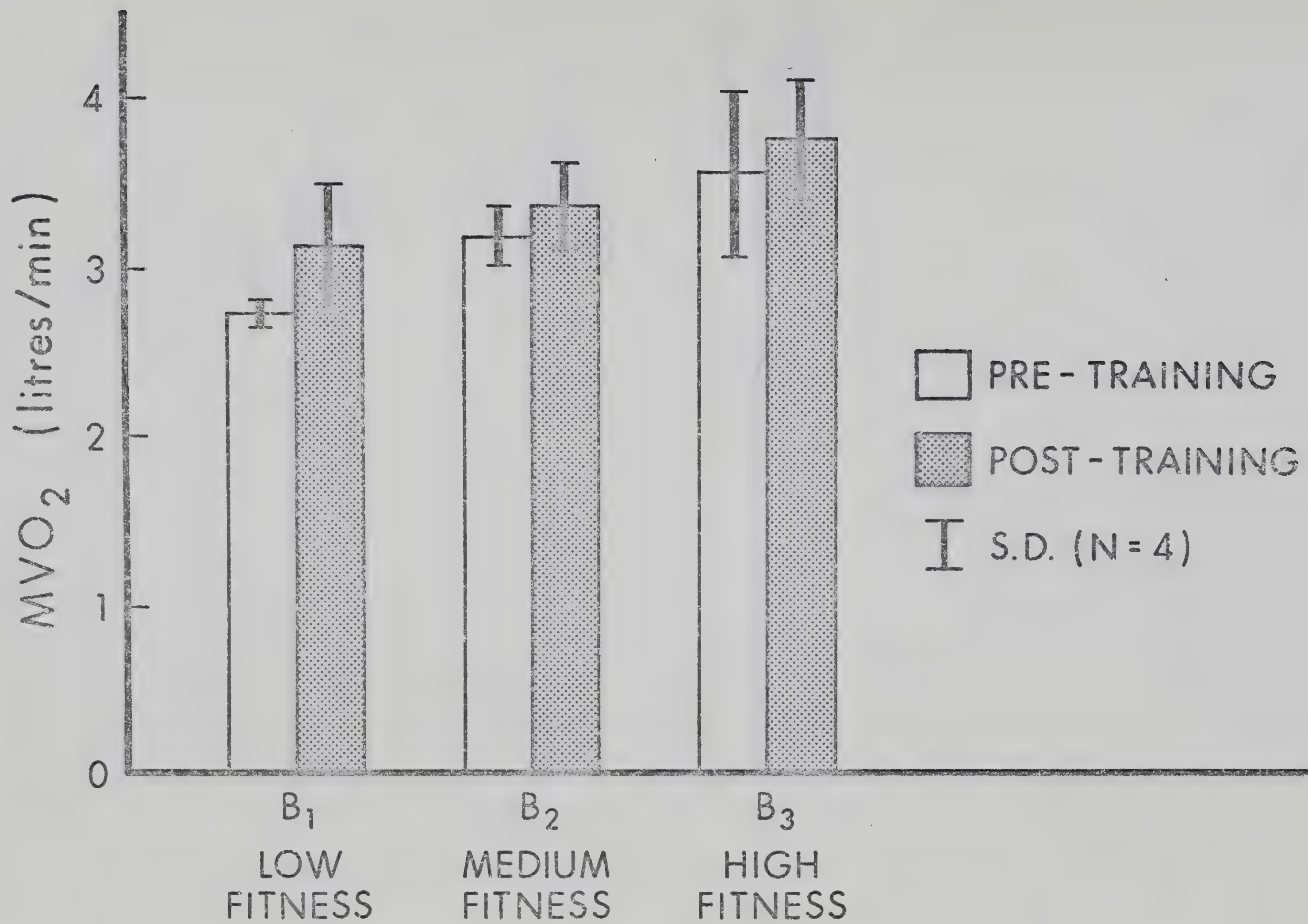

FIGURE 14 - $\dot{M}VO_2$ (litres/min) FOR BLOCKS IN GROUP T50

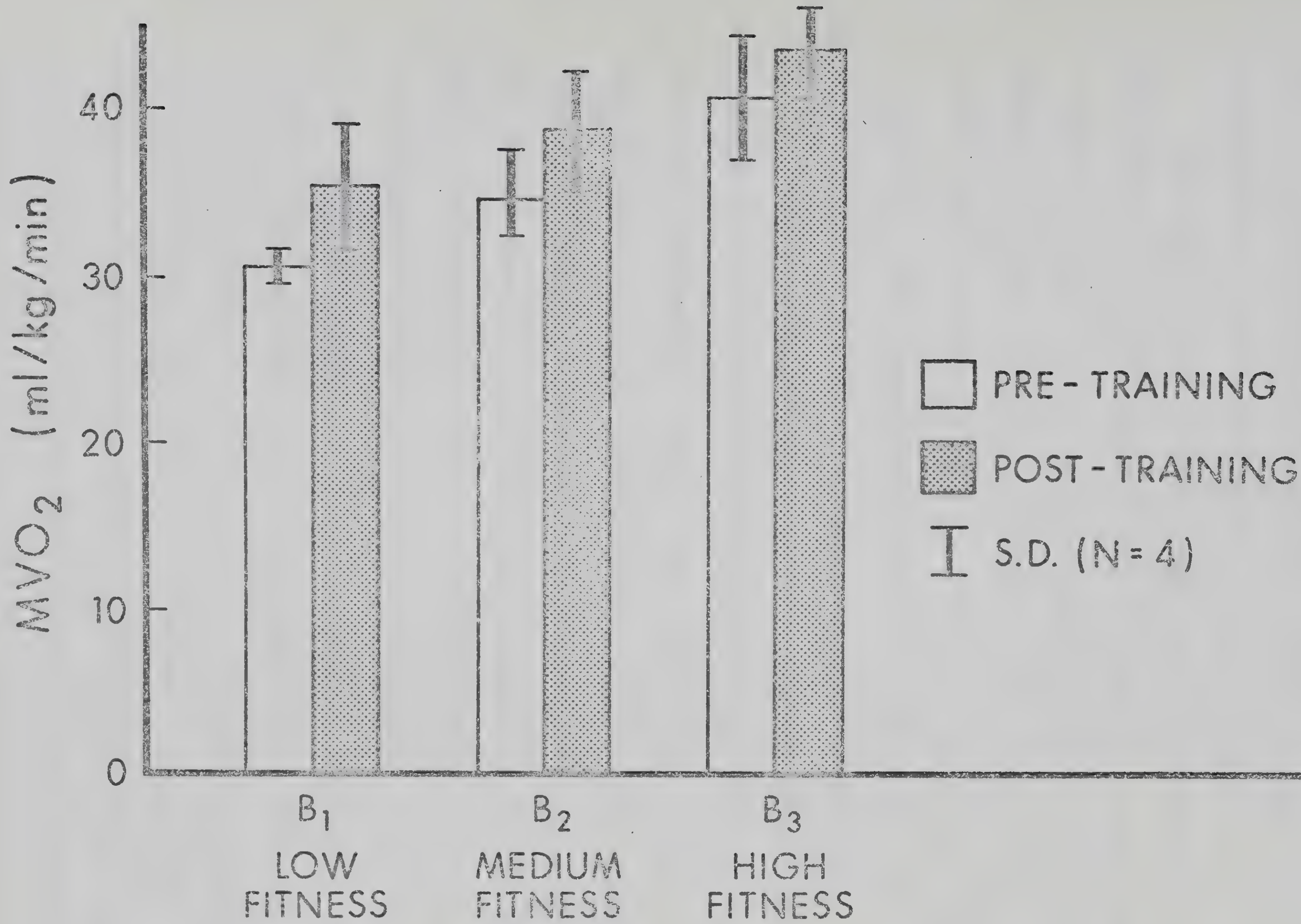

FIGURE 15 - $\dot{M}VO_2$ (ml/kg/min) FOR BLOCKS IN GROUP T50

$M\dot{V}O_2$ than the control group after the training program. The difference between the two training groups was not significant.

The $M\dot{V}O_2$ relative to body weight showed an increase of 3.33 and 4.06 ml per kg per minute for the T70 and T50 training groups respectively. The control group decreased by 0.07 ml per kg per minute. The three way ANOVA (Appendix H-1V,A) revealed significant time (C) and treatment X time (AC) effects. However the F ratio of a one way ANOVA (Appendix H-1V,B) to test for simple main effects of all treatments at the post training test was insignificant.

It was decided to compare the fitness blocks within each training group. A one way ANOVA (Appendix H-V,A) indicated that there was a significnat ($p \leqslant .05$) difference between the means of $M\dot{V}O_2$ (litres/min) of the blocks of group T70 at the pre training test as was expected because they were blocked into low, medium and high fitness levels. (Figure 12). The Newman-Keuls revealed that block 3 was significantly higher than blocks 2 and 3 which did not differ (Appendix H-V,B) A one way ANOVA (Appendix H-V1,A) showed a significant difference in $M\dot{V}O_2$ (litres/min) for the blocks in group T50 ($p \leqslant .05$). The Newman-Keuls test revealed that all three means for $M\dot{V}O_2$ (litres/min) were different for all blocks in group T50 at the pre training test (Figure 14). However a one way ANOVA for each training group at the post training test revealed there were no significant differences amongst the blocks of each training group. (Appendix V-C; V1,C). When the means of the $M\dot{V}O_2$ (ml/kg/min) were compared for each of the blocks in each training group (Figures 13 and 15) there were no significant differences amongst the blocks of the T70 training group at the post training test. However the

Newman-Keuls test revealed that block 3 of the T50 training group was significantly ($p \leq .05$) greater than the other two blocks.

MAXIMUM PULMONARY VENTILATION ($\dot{V}E$ Max)

The $\dot{V}E$ Max increased 5.09 and 4.93 litres per minute at STPD in the T70 and T50 groups respectively but the control group showed a decrease of 2.00 litres per minute at STPD over the training program (Figure 16). However none of the main effects or interaction effects from the three way ANOVA were significant (Appendix H-V11,A). Therefore no further analyses were warranted.

MAXIMUM BLOOD LACTATE CONCENTRATIONS (HLa Max)

As mentioned previously, the HLa Max on the pre training test was significantly ($p \leq .05$) higher for the control group than for the two training groups. At maximum oxygen uptake following the training program, the two training groups increased the HLa Max by 12.16 and 9.84 mg % (for the T70 and T50 groups respectively) while the control group decreased only 4.33 mg % (Figure 17). A one way ANOVA for simple main effects at the post training test indicated there was not a significant ($p \leq .01$) difference between the three treatments (Appendix H-V111,D).

VENTILATORY EQUIVALENT ($M\dot{V}E/M\dot{V}O_2$) at $M\dot{V}O_2$

The $M\dot{V}E/M\dot{V}O_2$ decreased slightly in all groups over the training program (Table 6). The three way ANOVA (Appendix H-1X,A) revealed no significant main effects or interaction effects so no comparisons of the means were warranted.

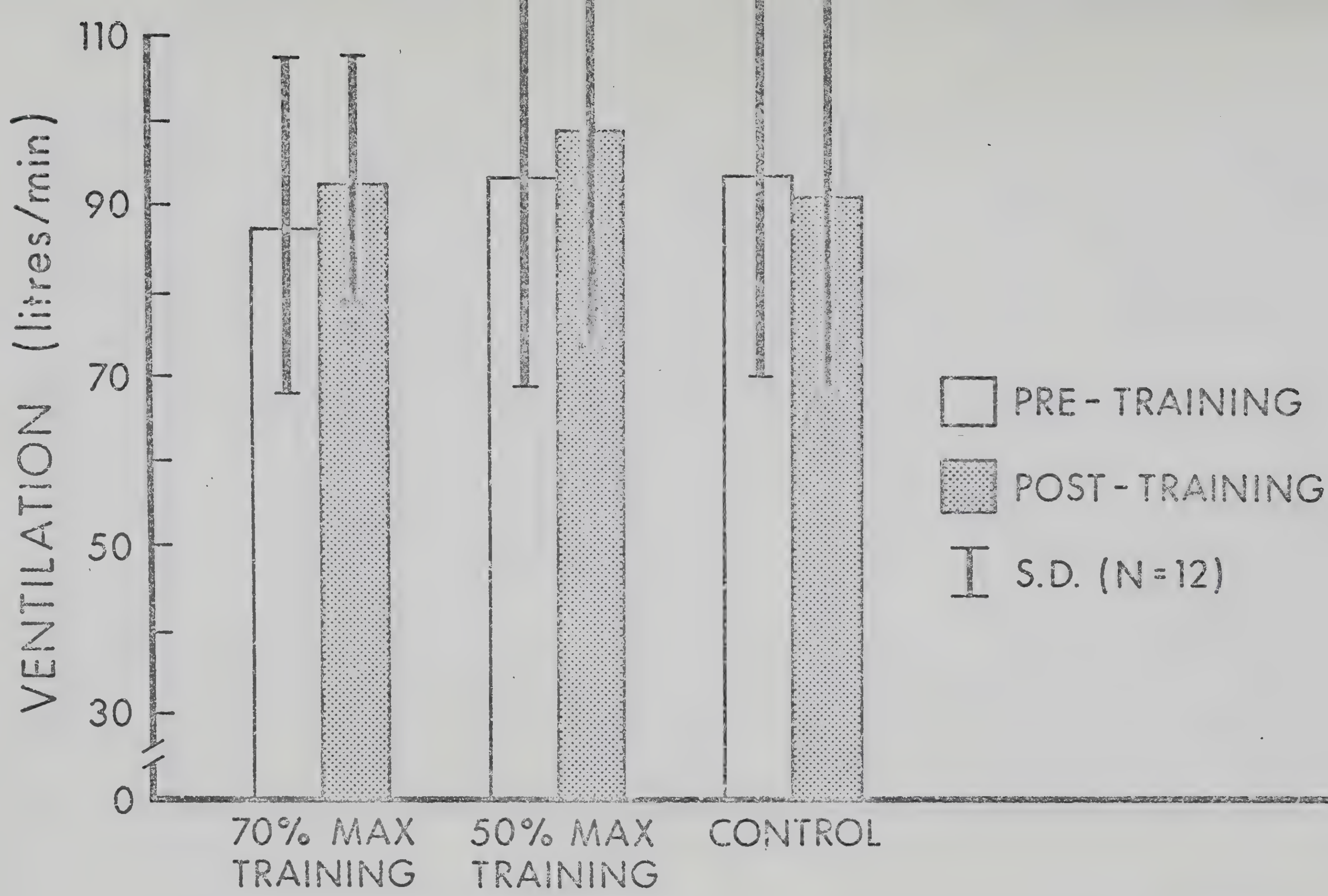

FIGURE 16 - MAXIMAL MINUTE VENTILATION FOR THE DIFFERENT TRAINING GROUPS

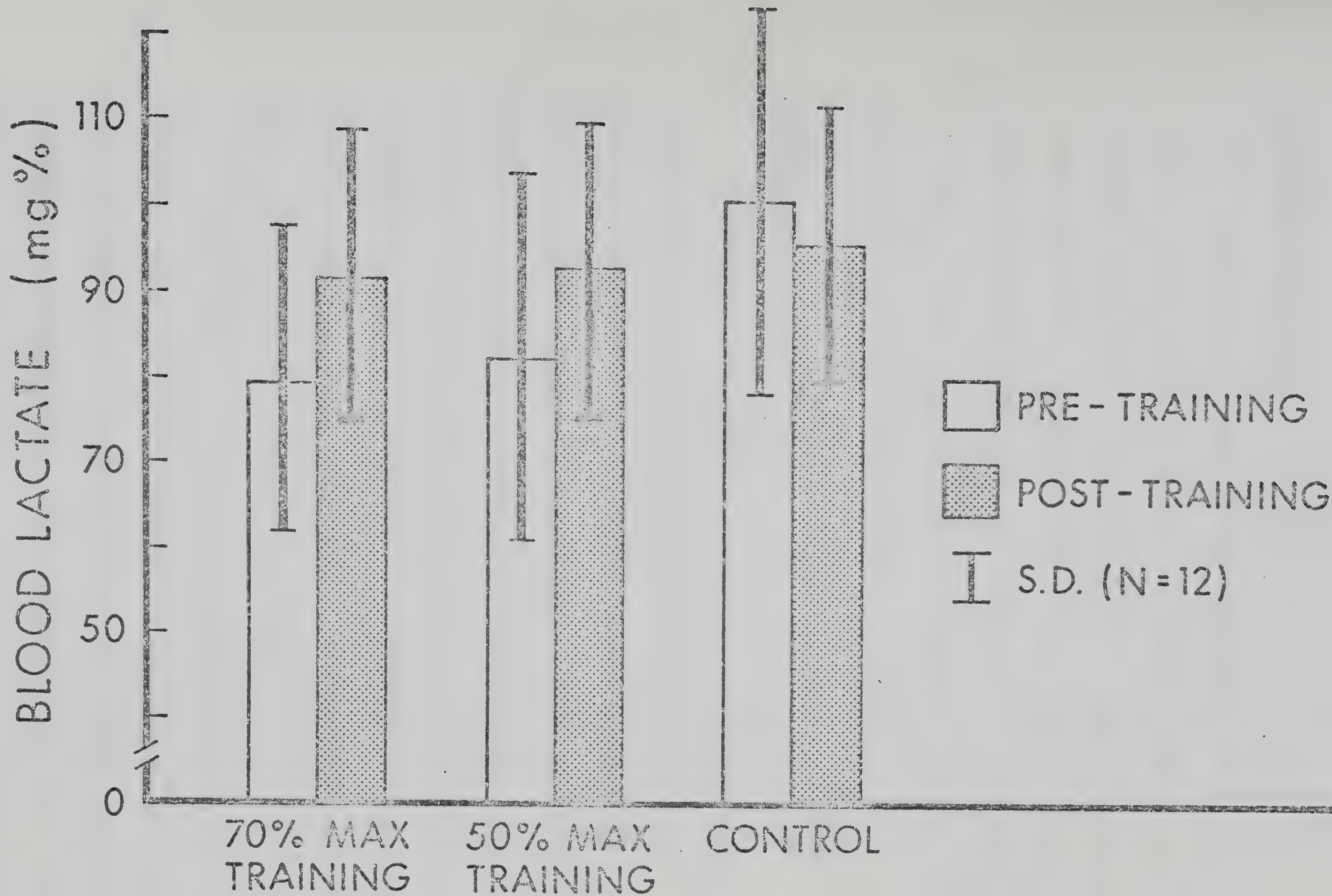

FIGURE 17 - MAXIMAL BLOOD LACTATE CONCENTRATIONS FOR THE DIFFERENT TRAINING GROUPS

MAXIMUM OXYGEN PULSE

The maximum oxygen pulse increased 1.69 and 2.15 ml per heart beat for the T70 and T50 groups respectively while the control group increased only 0.03 ml per heart beat. Statistically significant ($p \leq .001$) time (C) and treatment X time (AC) effects from a three way ANOVA (Appendix H-X,A) were obtained. A test for simple main effects for all treatment means at the post training test (Appendix H-X,B) resulted in an insignificant F ratio.

DISCUSSION

Generally information on endurance fitness can be obtained from physiological responses to the stress of submaximal or maximal work or from the rate of recovery following a standard intensity of work. Endurance fitness is achieved by man when the various processes involved in metabolic exchange are maintained as close to the resting state as is possible during performance of a strenuous task over a prolonged period of time, with the ability to work at a higher steady state, than one, more "unfit", and to restore promptly after work all equilibria which are disturbed.

More research is required for the selection of an optiumum training regime, with the training stimuli quantified, for the preparation of athletes and for the promotion of fitness within the community. Several studies (13, 32, 54, 65, 69, 74, 77) have shown that training programs of varying intensities and durations can elicit endurance fitness. However, these studies failed to quantify oxygen cost, total work, intensity and duration. Studies (23, 88,

TABLE 7

Summary Table of the Significant Changes with Training for the Various Parameters At Submaximal, Initial Maximal, and Maximal Work Loads.

Parameters	T1 (70% Max.)	T2 (50% Max.)	T3 (Control)
	SUBMAXIMAL WORK LOAD (900 Kpm/min.)		
Heart Rate (beats/min.)			
$\dot{V}O2$ (ml/kg/min.)			
$\dot{V}O2$ (litres/min.)			
$\dot{V}E$ (litres/min.)			
Lactate (Mg%)	*V	*V	
$\dot{V}E/\dot{V}O2$			
O2 Pulse (ml/beat)			
	INITIAL MAXIMAL WORK LOAD		
Heart Rate (beats/min.)	**V	**V	
$\dot{V}O2$ (ml/kg/min.)			
$\dot{V}O2$ (litres/min.)			
$\dot{V}E$ (litres/min.)	**V	**V	
Lactate (Mg%)	**V	**V	
$\dot{V}E/\dot{V}O2$	**V	**V	
O2 Pulse (ml/beat)			
	MAXIMAL WORK LOAD		
Work Load	**Λ	*Λ	
Heart Rate (beats/min.)			
$M\dot{V}O2$ (ml/kg/min.)			
$M\dot{V}O2$ (litres/min.)	*Λ	*Λ	
$M\dot{V}E$ (litres/min.)			
Lactate (Mg%)	*Λ	*Λ	
$\dot{V}E/\dot{V}O2$			
O2 Pulse (ml/beat)			

** Significant at .01
* Significant at .05
Λ Increase
V Decrease

89, 94, 109) which attempted to quantify the training stimulus failed to control total work, oxygen cost or initial abilities.

The training program used in this study was designed to equate training groups on total oxygen cost, initial ability and frequency of the training sessions, in order to determine if the oxygen cost of training is a primary contributor to endurance fitness. If the first group (70% maximum) improved more than the second group (50% maximum), intensity could be proposed as the training stimulus. If the second group showed more improvement, duration of the training sessions could be proposed as the training stimulus. If there was no difference between the groups ie. the same improvement in both groups, it could be argued that total oxygen cost had elicited the training effects.

Over the eight week program, the heart rate decreased at submaximal and initial maximal work loads in the two training groups as compared to the control. The decreases at the initial maximal work load of 20.42 and 21.59 beats per minute for the T70 and T50 groups were significantly different ($p \leq .01$) from the control. However, the decreases of 16.9 and 18.9 beats per minute, at the submaximal work load for the T70 and T50 groups respectively, although in line with the results reported by many researchers (30, 37, 47, 83, 85, 109), were not significant ($p < .05$). The factors governing the decrease in heart rate at submaximal work loads are multiple. Many authors (8, 37, 47, 82, 94) have suggested that the decrease in heart rate is due to either an increase in stroke volume and/or an increase in arterio-venous oxygen difference, or both effects

combined. Saltin et, al. (82) and Hartley et, al. (47) found that the cardiac output does not change at submaximal work and therefore concluded that the stroke volume increases, to compensate for the lower heart rate. Tabakin et, al.(101) however, reported a decrease in cardiac output at submaximal work after training, due to a decrease in heart rate and no change in stroke volume. Ekblom (37) attributed the decrease in heart rate to an increased arterio-venous oxygen difference rather than an increased stroke volume. He suggests that the increased arterio-venous oxygen difference might have been due to more complete oxygen extraction in the muscle or due to more effective regulation of the cardiac output and therefore more blood would be shunted to the active parts of the body from the inactive parts. Clausen (19) proposes that the directing of blood from non-active to active tissues does not occur at submaximal work loads as a result of training but rather the opposite occurs. Ekblom (37) has shown that cardiac output does decrease at submaximal work after training due to a decreased heart rate and an unchanged stroke volume. This would support the theory that oxygen extraction is increased. Holloszy (50) lends credence to this theory since he found training can increase the aerobic enzyme content and activity in rat muscle. Thus, the decrease in heart rate at submaximal work can be attributed to a decreased cardiac output and an increased arterio-venous oxygen difference, or to an increased stroke volume to maintain the cardiac output, or to a combination of both of the above effects. The difference between the T70 and T50 training groups on heart rates at the initial maximum work load were not different. Therefore it seems

probably that as long as the aerobic cost of training is the same at intensities of training equal to and greater than 50% of maximal oxygen consumption, optimum decreases in heart rate at submaximal work loads can be acheived. If the objective of training is to reduce cardiac work and time is limited, work at a high intensity can be prescribed for healthy people. However, if time is of no consequence and high intensity work is undesirable, a work load of 50% of maximum oxygen consumption with the same aerobic cost as the training above could be prescribed. A decrease in heart rate at submaximal work of the same magnitude should result with the high and low intensity programs.

The significant ($p \leq .05$) decreases in blood lactate at the submaximal work load (900 Kpm) and at the initial maximal work load ($p \leq .01$) for both training groups, are similar to the results obtained by Taylor et. al. (103) and Williams et. al. (111). Both studies showed that training can increase the percentage of maximum oxygen uptake at which anaerobic metabolism occurs. Åstrand and Rodahl (8) suggest that this decrease in anaerobic metabolism is a result of a more effective oxygen transport during the beginning of work. The work of Ekblom et. al. (37), Hartley et. al. (47) and Saltin et. al. (85) suggest that this decreased anaerobic metabolism at submaximal work could be due to an increased arterio-venous oxygen difference. There was a significant decrease in the pulmonary ventilation ($p \leq .01$) at the initial maximum work load for both training groups after the eight week program. Perhaps the decreased anaerobiosis could account for the decrease in ventilation. During work producing lactate the

pH of the blood falls slightly and the pCO_2 increases (8). Since the blood lactate was significantly lower at the initial maximum load after training in the two training groups, the respiratory rate would be decreased resulting in the significant decrease in pulmonary ventilation. There was no significant difference between the two training groups on the decreased lactate production at either the submaximal or initial maximal work loads. Therefore it seems that both training programs improve the efficiency of the aerobic system and decrease the involvement of the anaerobic energy processes.

Since the oxygen consumption at both the submaximal and the initial maximal work load did not change for both training groups, the training program did not improve the efficiency of bicycle riding. The results at submaximal work (900 Kpm) are in line with the results of Davies et. al. (30) who reported that the oxygen consumption at 900 Kpm remained unchanged during the training program.

The ventilatory equivalent ($\dot{V}E/\dot{V}O_2$) at the initial maximum load following training decreased significantly ($p < .01$) for both training groups over the control. This does not substantiate the work of Saltin et. al. (83), Saltin et. al. (85) and Wenger (109) who reported that changes in pulmonary ventilation were accompanied by proportional changes in oxygen consumption resulting in the ratio being unchanged. As was pointed out earlier, the decreased anaerobiosis could have accounted for the decrease in pulmonary ventilation at the initial maximum load. Therefore this change in lactate production could affect the pulmonary efficiency per se.

Both training groups demonstrated an increased lactic acid

tolerance over the training program (15.2% and 12% for the T70 and T50 groups respectively). The groups initially were equated on aerobic power after the pre training test and were not similar in the degree to which the anaerobic energy process were engaged (Figure 7). As mentioned previously, the HLa Max. on the pre training test was significantly ($p \leqslant .05$) higher for the control group than for the training groups. However at the post training test there was no significant difference between all three groups indicating there was an increased lactic acid tolerance for the training groups. These results are in line with those reported by Taylor et.al. (103), Williams et.al. (111) and Wenger (109). Therefore a similar tolerance to lactic acid can be achieved through training at 50 up to 70% of maximum oxygen consumption in which the aerobic cost is equal.

After the eight week training program the average maximal oxygen uptake increased 7.9% and 10.8% for the T70 and T50 groups respectively. This is very similar to the results obtained by Knehr et.al. (56) but somewhat lower than those found by many researchers. (35, 37, 47, 83, 85, 109). It is difficult to compare results of different studies with the changes reported in this study because of the little effort in attempting to quantify the training programs in terms of initial fitness levels, intensity of the training, frequency of the sessions, duration of each session, total work output, and aerobic cost. Wenger (109) equated the totalwork output and initial ability and reported that the intensity of the training program relative to maximal aerobic power is of primary

importance in producing optimal endurance fitness improvement. However in this study subjects of the same initial fitness in each of the training groups were yoked together so that the high fitness subjects actually performed more total work than the low fitness subjects. In this study where frquency and total aerobic cost were equated over all the subjects in the training groups, the fact that there was no significant difference between the improvements of the training groups indicates that the aerobic cost of the training is a critical determinant in improving endurance fitness as measured by maximum oxygen consumption.

There was no significant difference in maximum oxygen consumption (ml/kg/min) amongst the three groups after training. However if the improvements in $M\dot{V}O_2$ (ml/kg/min) of the different fitness levels within each training group are compared, the low fitness blocks (B_1) for the T70 and T50 training groups increased 16% and 15% respectively. The middle fitness blocks (B_2) increased 10.5% and 12% (for the T70 and T50 groups respectively), while the high fitness blocks (B_3) which had been moderately active before the study, showed the smallest increase in $M\dot{V}O_2$ (ml/kg/min) of 3.8% and 7.7% (for the T70 and T50 groups respectively). Since the low fitness blocks have a greater margin of improvement, there appears to be a trend of greater improvement in these low fitness levels.

The practical applicability of this trend in improvements of endurance fitness as measured by $M\dot{V}O_2$ would be the development of fitness programs for very unfit people with an intensity of 50% of maximum oxygen consumption and the aerobic cost equal to programs of higher intensities. When the circulatory system has adapted to

the low intensity training programs of higher intensity could be recommended without undue risk of heart attacks or injury.

An increased capacity to perform physical work is a primary requisite of an endurance training program. Both the T70 and T50 training groups increased their capacity to perform physical work over the eight week program. These was no significant difference between the two groups.

Thus it would seem in a training period extending over eight weeks and with the aerobic cost and initial ability equated, that the aerobic cost of the training is a critical determinant of an improved oxygen transport system.

As mentioned previously, Cooper (23) has devised a point system for fitness where each point is equal to seven millilitres of oxygen per kilogram of body weight. A good fitness however, is maintained or achieved by earning thirty points per week. Upon examination of the point system, equal points have not been given for an equal energy expenditure ie. a person working at a higher intensity is credited with more points for a lesser aerobic cost. Evidence from this study indicate that equal points should be given for an equal energy expenditure.

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY

Thirty-six volunteer subjects (mean age 37.4 years) were blocked into three levels of initial fitness as determined by their maximum oxygen consumption in ml per kg per minute. The twelve subjects in each fitness group were randomly assigned to one of three treatment groups. Thus the three groups were equated on initial fitness as measured by maximum oxygen consumption relative to body weight. The first treatment group (T70) trained at 70% of their $M\dot{V}O_2$; the second treatment group (T50) trained at 50% of their $M\dot{V}O_2$; and the third treatment group (C) served as a control. The training program consisted of three training sessions per week for eight weeks. The amount of oxygen to be consumed per training session (ml per kg per time) was determined by subject two in the low fitness block of the T70 training group. This subject was the poorest performer. As he increased his performance time and therefore his oxygen cost in ml per kg per time, the other subjects' work loads or times were adjusted so that they consumed the same amount of oxygen in ml per kg per time. Thus the total oxygen consumed in each session and the total oxygen consumed over the eight weeks was equal for all subjects of both training groups. Testing was done prior to and following the eight weeks of training.

The heart rates at the submaximal work load were lower for the two training groups compared to the control group following the eight

week program. The heart rates decreased 11% and 13% for T70 and T50 training groups respectively, however, this was not significant ($p < .05$).

The heart rates at the initial maximum work load were significantly ($p < .01$) lower for the two training groups compared to the control group following the training program. The difference between T70 and T50 groups, however, was not significant.

Blood lactate concentrations for the two training groups were significantly lower than the control after training at the submaximal work load ($p < .05$) and at the initial maximum workload ($p < .01$). The difference between the two training groups, however, was not significant.

Pulmonary ventilation was significantly ($p < .01$) lower in the two training groups at the initial maximum work load following training but the difference between the two training groups was not significant.

The ventilatory equivalent ($\dot{V}E/\dot{V}O_2$) was significantly ($p < .01$) lower in the two training groups at the initial maximum work load following training. There was no difference between the two training groups.

The work load which produced maximum oxygen consumption was significantly ($p < .05$) greater for the two training groups compared to the control group following the training program. The T70 group was also significantly ($p < .01$) higher from the control group. However no differences occurred between the two training groups.

Maximum oxygen consumption in the two training groups was significantly ($p < .05$) higher following the training than the

control group. However there was no significant difference between the two training groups.

There was no significant difference between the three groups for blood lactate concentrations at maximum oxygen consumption. However, at the initial maximum work load the control group was significantly ($p \leq .05$) higher than the training groups.

CONCLUSIONS

Since the two training groups showed similar substantial reductions in heart rate at the submaximum and at the initial maximum work load following training, it seems probable that any training (50% to 70%) with the same oxygen cost would be suitable in reducing cardiac work at submaximal work loads.

Since maximum oxygen consumption has been proposed as the best measure of endurance fitness and there was no significant difference between the increases of both training groups, it would be appropriate to suggest that the aerobic cost of the training is a critical determinant to an improved oxygen transport system.

A practical implication of these conclusions is that serious consideration should be given to allotting equal points to an equal energy expenditure in a system such as the Aerobics program of Cooper.

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APPENDIX A

AEROBIC COST FOR EACH TRAINING SESSION OVER THE EIGHT WEEK PROGRAM IN MILLILITRES PER KILOGRAM PER TIME.

AEROBIC COST FOR EACH TRAINING SESSION* OVER THE EIGHT WEEK PROGRAM IN MILLILITRES PER KILOGRAM PER TIME.

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
194.49	259.32	324.15	392.70	392.70	392.70	462	462

*There were three training sessions per week.

APPENDIX B

ENZYMATIC METHOD FOR DETERMINING THE LACTIC ACID CONTENT OF BLOOD

LACTIC ACID DETERMINATIONS:

NOTE

Do all tests in duplicate unless confident in results

A) Preparation of blood.

Add 2 mls of fresh heparinized blood to 4 mls cold 8% perchloric acid (P.C.A.) Seal & mix well. At this point, samples may be stored in refridgerator until ready to analyse. When ready to use, centrifuge and transfer clear protein free filtrate (PFF) to another test tube and recentrifuge if necessary to obtain clear supernatant.

B) Standard Curve.

Reagents Combine in erlenmeyer flask

60 mg. B-DPN (Keep in dessicator in deep freeze unit)
0-60 ml LDH suspension
12 ml glycine hydrazine buffer
24 ml distilled water
Cover and shake well.

Prepare 12 test tubes as follow.

(Lactic acid standard is made by diluting stock STO 1 ml with 4 ml H_2O)

Tube # (in duplicate)	Above Mixture (ml)	Lactic Acid Standard	L.A. mg %
1	3.0	0.0	0
2	2.9	0.1	12
3	2.8	0.2	24
4	2.7	0.3	36
5	2.6	0.4	48
6	2.5	0.5	60

Cover tubes. Mix well. Incubate at room temperature at least 45 minutes and read on Speck 20 at 340 mu.

Plot optical density versus L.A. concentration. Graph will not be a straight line on Speck 20. Graph should be useable day to day. Check it by running a standard each day. But will resemble this O.D.

Samples: supernatants must be clear

For each test to be done - you need

5mg. B-DPN
0.05 ml LDH
1 ml Glycine Buffer
2 ml H_2O

<u>Example:</u>

If doing 20 samples:

----- do them in duplicate -------------------	20 X 2 = 40
----- allow for blank ------------------------	2 X 1 = 2
----- allow for checking standard ------------	2 X 1 = 2
	44

Quantity required:

44 X 5 mg BDPN =	220 mg BDPN
44 X 0.05 ml LDH =	2.2 ml LDH
44 X 1 ml Glycine Buffer =	44 ml Glycine Buffer
44 X 2 ml H_2O =	88 ml H_2O

Label 2 test tubes for each sample.
To each tube add 2.9 ml of above mixture.
Add 0.1 ml of protein free filtrate mix and incubate 45 minutes.
Read at 340 mu.

For checking std re.: add 0.1 ml diluted std to 2.9 ml reagent = 12 mg %

or add 0.2 ml diluted std to 2.8 ml reagent = 24 mg %

or add 0.3 ml diluted std to 2.7 ml reagent = 36 mg %

APPENDIX C

RAW SCORES OBTAINED DURING SUBMAXIMAL WORK LOAD (900 KPM) AT PRE AND POST TRAINING TESTS

RAW SCORES OBTAINED DURING SUBMAXIMAL WORK LOAD (900 KPM) AT PRE-TRAINING TEST

Subjects	H R	% O_2	% CO_2	$\dot{V}E$ (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
T_{70} (70% $M\dot{V}O_2$)							
01	132	17.83	3.8	55.53	17	1.63	14.55
02	152	18.05	3.6	58.97	36	1.59	18.22
03	143	16.40	4.7	44.94	28	2.02	21.15
04	167	16.85	4.1	44.96	9	1.84	20.60
05	155	15.95	5.3	41.55	33	2.04	24.93
06	155	16.83	4.0	41.41	22	1.71	21.19
07	118	15.43	5.2	39.96	12	2.24	22.56
08	141	16.65	4.4	45.43	32	1.93	24.03
09	132	16.03	4.6	37.74	24	1.88	22.90
10	132	16.33	4.6	40.54	17	1.87	20.37
11	155	16.15	4.8	47.56	19	2.27	28.59
12	118	15.63	4.8	39.29	15	2.14	22.85

Continued:

Subjects	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
T_{50} (50% $M\dot{V}O_2$)							
01	155	16.75	4.4	44.94	29	1.86	20.31
02	167	15.73	4.9	40.39	19	2.14	25.02
03	167	15.73	4.8	41.39	24	2.14	23.05
04	150	16.58	4.8	48.91	22	2.07	23.55
05	142	15.60	5.2	37.26	22	2.00	20.11
06	132	17.18	4.0	58.65	33	2.17	21.89
07	145	16.63	4.4	48.73	45	2.09	23.94
08	141	16.65	4.4	45.43	19	1.93	24.03
09	155	18.65	4.3	63.99	22	1.95	22.29
10	138	16.75	4.2	47.97	16	2.00	25.37
11	132	16.75	4.2	50.39	30	2.11	22.40
12	148	16.20	4.4	48.79	27	2.35	26.70
Tc (Control)							
01	129	16.50	4.5	40.84	24	1.80	17.34

Subject	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
TC (Control)							
01	129	16.50	4.5	40.84	24	1.80	17.34
02	150	17.10	4.0	53.46	26	2.03	23.98
03	150	16.65	4.2	41.45	23	1.79	21.24
04	136	17.28	4.0	49.08	36	1.75	21.91
05	134	15.95	5.1	43.87	34	2.17	24.28
06	145	16.35	4.8	43.71	27	1.98	25.47
07	115	16.10	4.9	36.34	15	1.75	19.91
08	161	17.58	3.8	38.13	43	1.24	13.41
09	167	16.95	4.3	54.54	39	2.13	25.87
10	143	16.08	4.6	42.23	15	2.08	23.86
11	125	16.65	4.4	46.41	18	1.98	24.14
12	132	16.75	4.4	44.94	19	1.86	20.31

RAW SCORES OBTAINED DURING SUBMAXIMAL WORK LOAD (900 KPM) AT POST TRAINING TEST

Subject	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
T70 (70% M$\dot{V}O_2$)							
01	118	16.10	4.9	39.57	16	1.91	17.34
02	155	17.20	3.7	55.99	25	2.09	23.66
03	122	17.02	4.1	46.53	25	1.80	19.25
04	115	17.02	3.8	45.25	10	1.78	20.64
05	141	16.42	4.5	42.48	29	1.92	22.93
06	125	16.75	4.3	33.76	18	1.40	17.05
07	102	16.00	4.3	43.68	10	2.23	22.50
08	126	16.13	5.1	39.67	17	1.88	21.08
09	132	17.08	4.0	49.07	17	1.88	24.00
10	125	16.18	4.6	38.27	14	1.84	20.12
11	132	16.83	4.3	42.38	15	1.72	21.64
12	105	15.68	4.9	34.86	13	1.87	20.75

Continued:

Subject	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
T50 (50% $M\dot{V}O_2$)							
01	125	16.75	4.2	52.03	20	2.18	23.47
02	148	15.65	5.0	35.11	15	1.89	21.81
03	140	16.13	5.0	39.50	20	1.88	21.08
04	136	16.13	5.1	39.54	24	1.88	21.10
05	136	16.18	4.6	44.63	21	2.14	21.54
06	115	16.93	4.1	56.55	20	2.26	22.05
07	145	16.53	4.2	47.88	22	2.14	25.03
08	149	16.65	4.4	45.40	18	1.93	24.03
09	129	16.65	4.2	50.23	20	2.16	25.19
10	118	16.95	4.2	41.11	16	1.62	20.66
11	107	17.20	3.6	40.32	13	1.52	16.57
12	117	16.93	4.0	50.92	24	2.04	24.31

Subjects	H R	% O_2	% CO_2	$\dot{V}E$ (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
TC (Control)							
01	129	16.50	4.5	41.00	20	1.82	17.34
02	155	17.10	4.0	55.64	30	2.08	23.99
03	150	16.65	4.0	42.45	21	1.84	21.43
04	123	17.20	4.2	52.33	36	1.89	23.64
05	134	15.66	5.0	40.78	33	2.10	24.20
06	148	16.35	4.8	43.71	26	1.98	25.47
07	115	16.12	4.8	38.34	18	1.80	20.01
08	161	17.58	3.8	45.13	40	1.75	20.04
09	167	16.95	4.3	50.54	40	2.01	24.02
10	133	16.63	3.9	50.51	13	2.23	26.13
11	125	16.65	4.4	37.05	17	1.58	19.17
12	132	18.18	2.8	67.68	15	1.86	21.22

APPENDIX D

RAW SCORES OBTAINED DURING INITIAL MAXIMAL WORK LOADS AT PRE AND POST TRAINING TESTS

RAW SCORES OBTAINED DURING INITIAL MAXIMAL WORK LOAD AT PRE-TRAINING TEST

Subject	W.L. (KPM)	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
T_{70} (70% MVO_2)								
01	1500	180	16.58	5.5	65.97	71	2.68	23.95
02	1350	195	18.38	3.0	109.19	84	2.67	30.87
03	1350	180	17.08	4.2	78.43	87	2.96	30.99
04	1350	173	16.48	4.8	64.80	52	2.83	31.80
05	1350	187	16.98	4.4	69.98	67	2.69	32.00
06	1350	187	17.28	3.9	75.44	70	2.71	33.55
07	1800	184	16.38	4.9	81.99	67	3.67	36.99
08	1350	180	17.45	3.9	91.00	71	3.65	37.60
09	1800	180	17.43	3.8	92.04	111	3.16	38.43
10	1800	200	17.80	3.8	127.39	104	3.77	41.07
11	1500	187	16.80	4.6	91.43	75	3.67	46.13
12	1800	180	16.85	4.6	102.06	97	3.57	39.01

Subject	W.L. (KPM)	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
T_{50} (50% MVO_2)								
01	1350	173	17.90	3.6	95.99	119	2.77	29.88
02	1350	204	16.18	5.2	56.58	57	2.64	30.84
03	1350	180	16.30	4.8	70.00	74	2.70	30.00
04	1200	184	16.85	4.3	68.14	70	2.75	31.14
05	1500	173	17.78	3.6	105.30	92	3.21	32.21
06	1500	180	17.63	4.0	107.38	101	3.36	33.91
07	1500	180	17.68	3.7	96.64	97	3.04	34.83
08	1350	187	17.45	3.9	89.21	62	3.01	37.44
09	1350	187	17.65	4.0	104.49	67	3.23	37.67
10	1800	173	16.95	4.1	75.85	54	3.00	37.94
11	1800	173	18.18	2.8	143.72	101	3.95	42.02
12	1650	180	17.23	4.2	111.93	94	4.01	45.47

Subject	W.L. (KPM)	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
TC (Control)								
01	1350	173	16.37	4.7	58.55	66	2.65	25.45
02	1350	180	18.23	3.3	94.38	128	2.41	28.53
03	1350	195	17.13	4.3	68.81	68	2.53	30.13
04	1350	173	17.70	3.8	80.41	90	2.48	31.03
05	1350	191	16.45	4.8	64.78	87	2.85	31.85
06	1500	184	17.60	4.0	85.38	99	2.70	34.72
07	1800	184	17.40	4.5	96.64	104	3.17	36.15
08	1200	173	18.05	2.8	117.72	93	3.42	37.11
09	1350	204	18.00	3.3	110.54	91	3.14	38.16
10	2100	173	17.45	3.7	106.93	128	3.67	42.02
11	1800	173	17.55	4.0	107.52	111	3.47	42.13
12	1950	187	17.88	3.6	134.81	136	3.93	43.06

RAW SCORES OBTAINED DURING INITIAL MAXIMAL WORK LOADS AT POST-TRAINING TEST

Subject	W.L. (KPM)	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
T_{70} (70% MVO_2)								
01	1500	155	16.25	5.2	59.98	29	2.73	24.80
02	1350	187	18.05	3.2	101.04	79	2.83	31.95
03	1350	161	17.15	4.2	71.06	45	2.61	27.90
04	1350	141	17.03	4.2	77.52	34	2.97	34.41
05	1350	167	16.75	4.7	61.98	62	2.51	30.01
06	1350	161	16.40	4.8	48.95	40	2.19	26.58
07	1800	167	16.25	4.9	73.08	44	3.38	34.14
08	1350	155	16.65	4.9	64.00	40	3.08	39.42
09	1800	173	17.03	4.5	82.06	57	3.08	39.42
10	1800	173	16.65	4.8	91.35	57	3.77	41.33
11	1500	161	16.45	4.9	65.65	59	3.87	36.13
12	1800	167	15.75	5.6	64.33	63	3.26	36.28

Subjects	W.L. (KPM)	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	VO_2 (Liters/min)	VO_2 (ml/kg/min)
T_{50} (50% MVO_2)								
01	1350	155	16.95	4.4	75.72	50	2.95	31.76
02	1350	161	15.83	4.4	48.22	37	2.56	29.50
03	1350	167	16.00	4.6	50.20	36	2.50	29.00
04	1200	155	16.20	5.0	51.48	35	2.40	28.94
05	1500	167	17.03	4.2	78.31	78	3.00	30.17
06	1500	155	17.00	4.2	86.09	74	3.33	32.55
07	1500	167	16.53	4.2	47.88	70	3.00	34.70
08	1350	161	16.70	4.5	60.60	42	2.50	31.25
09	1350	161	16.78	4.3	77.65	51	3.20	37.28
10	1800	150	16.70	4.5	58.73	34	2.44	30.50
11	1800	155	17.55	3.3	109.20	69	3.72	40.54
12	1650	161	16.88	4.3	80.32	65	3.21	38.19

Subject	W.L. (KPM)	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
TC (Control)								
01	1350	173	16.37	4.7	59.00	72	2.56	24.61
02	1350	180	18.23	3.6	96.38	120	2.44	29.05
03	1350	190	17.13	4.3	68.00	69	2.50	29.70
04	1350	173	17.25	4.1	74.27	107	2.66	33.21
05	1350	187	16.45	4.8	64.78	88	2.80	31.10
06	1500	187	17.60	4.2	86.83	101	3.75	35.20
07	1800	184	17.40	4.4	97.00	100	3.07	34.90
08	1200	173	18.05	3.0	107.27	90	3.32	36.09
09	1350	200	17.97	3.0	109.45	94	3.20	39.02
10	2100	173	17.50	4.0	108.47	111	3.57	41.72
11	1800	173	17.55	4.0	107.52	86	3.47	42.13
12	1950	180	17.72	3.9	130.09	111	3.90	42.79

APPENDIX E

RAW SCORES OBTAINED DURING MAXIMAL

WORK LOADS AT POST-TRAINING TEST

RAW SCORES OBTAINED DURING MAXIMAL WORK LOADS AT POST-TRAINING TEST.

Subject	W.L. (KPM)	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
T_{70} (70% $M\dot{V}O_2$)								
01	1800	173	16.55	5.0	73.14	76	3.13	28.47
02	1500	187	18.20	2.7	101.04	93	2.83	31.95
03	1650	187	17.70	3.6	99.83	99	3.13	33.48
04	1800	173	17.25	4.2	103.91	88	3.60	42.72
05	1800	187	17.42	4.0	94.13	101	3.18	38.06
06	1650	187	16.65	4.8	67.52	66	2.80	34.06
07	2100	167	16.48	4.2	79.80	74	3.62	36.48
08	1950	187	16.58	4.4	93.00	105	4.30	46.20
09	2100	180	17.95	3.4	113.36	125	3.26	41.71
10	2100	187	17.35	3.8	106.99	79	3.79	41.50
11	2100	184	16.75	4.9	86.01	110	3.44	43.22
12	2100	180	16.58	4.4	92.13	86	4.00	44.54

Subject	W.L. (KPM)	H R	% O_2	% CO_2	$\dot{V}$ E (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
T_{50} (50% $M\dot{V}O_2$)								
01	1650	176	17.80	3.6	121.82	100	3.67	39.59
02	1650	187	16.40	4.8	67.68	90	3.02	34.82
03	1500	180	16.98	4.5	67.52	76	3.05	35.00
04	1500	180	16.98	4.5	67.52	65	2.79	31.34
05	1800	173	17.53	3.6	102.72	101	3.45	34.69
06	1800	187	17.50	3.8	115.21	111	3.85	37.62
07	1650	187	16.95	4.1	89.88	102	3.56	41.61
08	1650	187	17.00	4.0	91.50	92	3.34	41.75
09	1650	187	17.43	3.8	105.50	97	3.62	42.18
10	2100	173	17.03	4.2	87.26	54	3.35	41.87
11	2100	173	18.10	3.2	154.73	114	4.26	46.37
12	2100	173	17.50	3.7	113.02	104	3.80	45.25

Subject	W.L. (KPM)	H R	% O_2	% CO_2	$\dot{V}E$ (STPD)	LACTATE (mg. %)	$\dot{V}O_2$ (Liters/min)	$\dot{V}O_2$ (ml/kg/min)
TC (Control)								
01	1350	173	16.37	4.7	59.00	72	2.56	24.61
02	1350	180	18.23	3.6	96.38	120	2.44	29.05
03	1350	190	17.13	4.3	68.00	69	2.50	29.70
04	1350	173	17.25	4.1	74.27	107	2.66	33.21
05	1350	187	16.45	4.8	64.78	88	2.80	31.10
06	1500	187	17.60	4.2	86.83	101	2.75	35.20
07	1800	184	17.40	4.4	97.00	100	3.07	34.90
08	1200	173	18.05	3.0	107.27	90	3.32	36.09
09	1350	200	17.97	3.0	109.45	94	3.20	39.02
10	2100	173	17.50	4.0	108.47	111	3.57	41.72
11	1800	173	17.55	4.0	107.52	86	3.47	42.13
12	1800	180	17.72	3.9	130.09	111	3.90	42.79

APPENDIX F

STATISTICAL ANALYSIS OF DATE OBTAINED AT SUBMAXIMAL WORK LOAD (900 KPM/min) PRIOR TO AND FOLLOWING TRAINING

APPENDIX F-1

(A) THREE WAY ANALYSIS OF VARIANCE FOR HEART RATE (beats per min) AT SUBMAXIMAL WORK LOAD (900 KPM/min)

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	12592	35			
A	581	2	290	0.76	0.47
B	1020	2	510	1.34	0.27
AB	700	4	175	0.46	0.76
Subj w Group	10291	27	381		
Within Subj	5647	36			
C	2738	1	2738	55.05	0.00
AC	1119	2	559	11.25	0.00
BC	121	2	60	1.22	0.31
ABC	326	4	81	1.64	0.19
C X Subj W G	1343	27	49		

(B) TEST FOR SIMPLE MAIN EFFECTS FOR HEART RATE (beats per min) AT SUBMAXIMAL WORK LOAD (900 KPM/min) AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	$_{33}^{2}F$ Crit.
Groups	1350	675.31	2	3.14	$\alpha .01=5.31$
Error	7100	215.17	33		$\alpha .05=3.29$

APPENDIX F-11

(A) THREE WAY ANALYSIS OF VARIANCE FOR OXYGEN CONSUMPTION (litres/min) AT SUBMAXIMAL WORK LOAD (900 KPM/min)

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	1.96	35			
A	0.24	2	0.12	2.11	0.14
B	3.83	2	0.19	0.33	0.72
AB	0.12	4	0.31	0.55	0.70
Subj w Group	1.56	27	0.57		
Within Subj	1.14	36			
C	0.36	1	0.36	1.28	0.26
AC	0.55	2	0.27	0.97	0.39
BC	0.19	2	0.95	3.36	0.04
ABC	0.95	4	0.23	0.84	0.51
C X Subj W G	0.76	27	0.28		

APPENDIX F-111

(A) THREE WAY ANALYSIS OF VARIANCE FOR OXYGEN CONSUMPTION (millilitres per kg of body weight per minute) AT SUBMAXIMAL WORK LOAD (900 KPM/min)

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	403	35			
A	22	2	11	0.94	0.40
B	40	2	20	1.71	0.20
AB	21	4	5	0.46	0.76
Subj w Group	319	27	11.8		
Within Subj	154.77	36			
C	4.41	1	4.41	1.11	0.30
AC	7.46	2	3.73	0.94	0.40
BC	16.10	2	8.05	2.03	0.15
ABC	19.54	4	4.88	1.23	0.32
C X Subj W G	107.28	27	3.97		

APPENDIX F-1V

(A) THREE WAY ANALYSIS OF VARIANCE FOR VENTILATION (litres/min STPD) AT SUBMAXIMAL WORK LOAD (900 KPM)

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	2403.37	35			
A	110.50	2	55.25	1.00	0.38
B	141.37	2	70.68	1.27	0.29
AB	652.50	4	163.12	2.94	0.03
Subj w Group	1499.00	27	55.51		
Within Subj	945.43	36			
C	12.12	1	12.12	0.45	0.51
AC	101.75	2	50.87	1.87	0.17
BC	9.62	2	4.81	0.18	0.83
ABC	87.18	4	21.79	0.80	0.53
C X Subj W G	734.75	27	27.21		

APPENDIX F-V

(A) THREE WAY ANALYSIS OF VARIANCE FOR BLOOD LACTATE CONCENTRATION (mg%) AT SUBMAXIMAL WORK LOAD (900 KPM/min)

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	4109.44	35			
A	489.69	2	244.84	2.06	0.14
B	360.02	2	180.01	1.52	0.23
AB	52.47	4	13.11	0.11	0.97
Subj w Group	3207.25	27	118.78		
Within Subj	833.00	36			
C	280.05	1	280.05	17.91	0.00
AC	86.35	2	43.17	2.76	0.08
BC	22.02	2	11.01	0.70	0.50
ABC	22.32	4	5.58	0.36	0.83
C X Subj W G	422.25	27	15.63		

(B) TEST FOR SIMPLE MAIN EFFECTS FOR BLOOD LACTATE CONCENTRATIONS (mg%) AT SUBMAXIMAL WORK LOAD (900 KPM/min) AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}^{2}_{33}F$ Crit.
Groups	434	217.44	2	4.54	α .01=5.31
Error	1580	47.90	33		α .05=3.29

APPENDIX F-V

(C) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR BLOOD LACTATE CONCENTRATIONS (mg%) AT SUBMAXIMAL WORK LOAD (900 KPM/min) AT POST TRAINING TEST

		3	2	1
	Means	25.583	19.417	17.417
1	17.417	*8.167	2.000	0.0
2	19.417	*6.167	0.0	
3	25.583	0.0		

*Significant at α .05

Critical Values	r=2	r=3
q .99 (r,33) $\sqrt{MS}$ within/n	7.74	8.86
q .95 (r,33) $\sqrt{MS}$ within/n	5.75	7.74

Mean 1 = T70 group
Mean 2 = T50 group
Mean 3 = Control group

APPENDIX F-V1

(A) THREE WAY ANALYSIS OF VARIANCE FOR VENTILATION EQUIVALENT (ventilation in litres per min divided by oxygen consumption in litres per minute) AT SUBMAXIMAL WORK LOAD (900 KPM/min)

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	985.05	35			
A	20.66	2	10.33	0.56	0.57
B	103.48	2	51.74	2.80	0.07
AB	362.30	4	90.57	4.90	0.004
Subj w Group	498.60	27	18.46		
Within Subj	515.93	36			
C	9.67	1	9.67	1.01	0.32
AC	35.65	2	17.82	1.86	0.17
BC	90.11	2	45.05	4.71	0.01
ABC	121.97	4	30.49	3.18	0.02
C X Subj W G	258.55	27	9.57		

APPENDIX F-V11

(A) THREE WAY ANALYSIS OF VARIANCE FOR OXYGEN PULSE (millilitres of oxygen per heart beat) AT SUBMAXIMAL WORK LOAD (900 KPM)

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	270.88	35			
A	12.12	2	6.06	0.71	0.49
B	20.60	2	10.30	1.21	0.31
AB	7.73	4	1.93	0.23	0.92
Subj w Group	229.91	27	8.51		
Within Subj	93.06	36			
C	19.60	1	19.60	9.49	0.004
AC	4.73	2	2.36	1.15	0.33
BC	7.03	2	3.51	1.70	0.20
ABC	5.85	4	1.46	0.71	0.59
C X Subj W G	55.81	27	2.06		

APPENDIX G

STATISTICAL ANALYSIS OF DATA OBTAINED AT INITIAL MAXIMAL WORK LOADS PRIOR TO AND FOLLOWING TRAINING

APPENDIX G-1

(A) THREE WAY ANALYSIS OF VARIANCE FOR HEART RATE AT INITIAL MAXIMUM WORK LOAD IN BEATS PER MINUTE

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	6013	35			
A	1619	2	809	5.36	0.01
B	33	2	16	0.11	0.89
AB	285	4	71	0.47	0.75
Subj w Group	4075	27	150		
Within Subj	6191	36			
C	3770	1	3770	128.20	0.00
AC	1538	2	769	26.15	0.00
BC	21	2	10	0.36	0.70
ABC	68	4	17	0.58	0.68
C X Subj W G	794	27	29		

(B) TEST FOR SIMPLE MAIN EFFECTS FOR HEART RATE AT INITIAL MAXIMUM LOAD BETWEEN TREATMENTS AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}^{2}_{33}F$ Crit.
Group	3094	1547.19	2	19.41	α.01=5.31
Error	2629	79.69	33		α.05=3.29

APPENDIX G-1

(C) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR HEART RATE AT INITIAL MAXIMUM WORK LOAD IN BEATS PER MINUTE

		3	1	2
	Means	181.083	164.000	159.583
2	159.583	**21.500	4.417	0.0
1	164.000	**17.083	0.0	
3	181.083	0.0		

**Significant at $\alpha = .01$

Critical Values	r = 2	r = 3
q .99 (r,33) $\sqrt{MS}$ within/n	10.01	11.48
q .95 (r,32) $\sqrt{MS}$ within/n	7.46	9.00

APPENDIX G-11

(A) THREE WAY ANALYSIS OF VARIANCE FOR OXYGEN CONSUMPTION AT INITIAL MAXIMUM LOAD IN LITRES PER MINUTE

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	12.85	35			
A	0.15	2	.0079	0.04	0.96
B	7.12	2	3.56	18.23	0.00
AB	0.43	4	0.10	0.56	0.69
Subj w Group	5.27	27	0.19		
Within Subj	1.60	36			
C	0.46	1	0.46	18.26	0.00
AC	0.19	2	.09	3.75	0.03
BC	0.15	2	.07	3.07	0.06
ABC	0.10	4	.02	1.06	0.39
C X Subj W G	0.68	27	.02		

APPENDIX G-111

(A) THREE WAY ANALYSIS OF VARIANCE FOR OXYGEN CONSUMPTION AT INITIAL MAXIMUM LOAD IN MILLILITRES PER KG OF BODY WEIGHT PER MINUTE

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	1738.62	35			
A	10.62	2	5.31	0.36	0.69
B	1302.06	2	651.03	44.47	0.00
AB	30.68	4	7.67	0.52	0.71
Subj w Group	395.25	27	14.63		
Within Subj	183.25	36			
C	34.37	1	34.37	8.77	0.006
AC	17.25	2	8.62	2.20	0.13
BC	18.37	2	9.18	2.34	0.11
ABC	7.43	4	1.85	0.47	0.75
C X Subj W G	105.81	27			

APPENDIX G-1V

(A) THREE WAY ANALYSIS OF VARIANCE FOR VENTILATION (litres per min STPD) AT INITIAL MAXIMUM LOAD

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	28226	35			
A	2622	2	1311	2.53	0.09
B	9126	2	4563	8.81	0.001
AB	2485	4	6213	1.20	0.33
Subj w Group	13992	27	5182		
Within Subj	7144	36			
C	3570	1	3570	97.97	0.00
AC	1697	2	848	23.29	0.00
BC	520	2	260	7.14	0.003
ABC	373	4	93	2.56	0.06
C X Subj W G	983	27	36		

(B) TEST FOR SIMPLE MAIN EFFECTS FOR VENTILATION (litres per min STPD) AT INITIAL MAXIMUM WORK LOAD AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}^{2}_{33}F$ Crit.
Groups	3997	1998.62	2	5.72	α .01=5.31
Error	11536	349.58	33		α .05=3.29

APPENDIX G-1V

(C) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR VENTILATION (litres/min) AT INITIAL MAXIMUM WORK LOAD

		3	1	2
	Means	92.422	71.750	68.700
2	68.700	**23.722	3.050	0.0
1	71.750	*20.672	0.0	
3	92.422	0.0		

**Significant at α = .01

*Significant at α = .05

Critical Values	r = 2	r = 3
q .99 (r,33) $\sqrt{MS}$ within/n	21.01	24.03
q .95 (r,33) $\sqrt{MS}$ within/n	15.00	18.85

APPENDIX G-V

(A) THREE WAY ANALYSIS OF VARIANCE FOR BLOOD LACTATE CONCENTRATION (mg%) AT INITIAL MAXIMUM LOAD

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	34159	35			
A	15835	2	7917	15.59	0.00
B	2513	2	1256	2.47	0.10
AB	2093	4	523	1.03	0.40
Subj w Group	13716	27	508		
Within Subj	13601	36			
C	7729	1	7729	88.47	0.00
AC	2417	2	1208	13.83	0.00
BC	358	2	179	2.05	0.14
ABC	736	4	184	2.11	0.10
C X Subj W G	2359	27	87		

(B) TEST FOR SIMPLE MAIN EFFECTS FOR BLOOD LACTATE CONCENTRATIONS (mg%) AT INITIAL MAXIMUM LOAD BETWEEN TREATMENTS AT PRE TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}^{2}_{33}F$ Crit.
Groups	2956	1478.00	2	3.57	α.01=5.31
Error	13680	414.55	33		α.05=3.29

APPENDIX G-V

(C) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR BLOOD LACTATE CONCENTRATION (mg%) AT INITIAL MAXIMUM LOAD AT PRE TRAINING TEST

		3	2	1
	Means	100.083	82.333	79.667
1	79.667	*20.417	2.667	0.0
2	82.333	*17.750	0.0	
3	100.083	0.0		

*Significant at α = .05

Critical Values	r = 2	r = 3
q .99 (r,33) $\sqrt{MS}$ within/n	22.83	26.12
q .95 (r,33) $\sqrt{MS}$ within/n	16.96	20.32

APPENDIX G-V1

(A) THREE WAY ANALYSIS OF VARIANCE FOR BLOOD LACTATE CONCENTRATION (mg%) AT INITIAL MAXIMUM LOAD

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	34159	35			
A	15835	2	7917	15.59	0.00
B	2513	2	1256	2.47	0.10
AB	2093	4	523	1.03	0.40
Subj w Group	13716	27	508		
Within Subj	13601	36			
C	7729	1	7729	88.47	0.00
AC	2417	2	1208	13.83	0.00
BC	358	2	179	2.05	0.14
ABC	736	4	184	2.11	0.10
C X Subj W G	2359	27	87		

(B) TEST FOR SIMPLE MAIN EFFECTS FOR BLOOD LACTATE CONCENTRATIONS (mg%) AT INITIAL MAXIMUM LOAD BETWEEN TREATMENTS AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}^{2}_{33}F$ Crit.
Groups	15296	7648.44	2	31.17	α .01=5.31
Error	8097	245.38	33		α .05=3.29

APPENDIX G-V1

(C) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR BLOOD LACTATE CONCENTRATIONS (mg%) AT INITIAL MAXIMUM LOAD AT POST TRAINING TEST

		3	2	1
	Means	95.750	53.417	50.750
1	50.750	**45.000	2.667	0.0
2	53.417	**42.333	0.0	
3	95.750	0.0		

**Significant at α =.01

Critical Values	r = 2	r = 3
q .99 (r,33) $\sqrt{MS}$ within/n	17.58	19.11
q .95 (r,33) $\sqrt{MS}$ within/n	13.06	15.77

APPENDIX G–V1

(D) SCHEFFE'S CONTRAST

Groups	C_1	$T70_1$	$T50_1$	C_2	$T70_2$	$T50_2$				
MEANS	100.08	79.67	82.33	95.75	50.75	53.42	$\Sigma C\bar{X}$	$(\Sigma C\bar{X})^2$	$\Sigma \frac{C^2}{n}$	MSw
Coefficients_1	-1	1	0	1	-1	0	24.59	605.16	1/4	245.38
Coefficients_2	-1	0	1	1	0	-1	24.58	605.16	1/4	245.38

$$S_1 = \frac{(\Sigma C\bar{X})^2}{(\Sigma \frac{C^2}{n}) \text{ MS within}} = \frac{605.16}{61.44} = 9.92$$

$$S_2 = \frac{(\Sigma C\bar{X})^2}{(\Sigma \frac{C^2}{n}) \text{ MS within}} = \frac{605.16}{61.44} = 9.92$$

${}^{2}_{33}F$ Crit. α .01 = 5.39

APPENDIX G-V11

(A) THREE WAY ANALYSIS OF VARIANCE FOR VENTILATORY EQUIVALENT IN LITRES OF VENTILATION PER LITRE OF OXYGEN CONSUMED PER MINUTE AT INITIAL MAXIMUM LOAD

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	1508	35			
A	301	2	150	3.98	0.03
B	49	2	24	0.65	0.53
AB	134	4	33	0.89	0.48
Subj w Group	1023	27	37		
Within Subj	462	36			
C	190	1	190	39.11	0.00
AC	100	2	50	10.33	0.00
BC	8	2	4	0.83	0.44
ABC	32	4	8	1.65	0.19
C X Subj W G	131	27	4		

(B) TEST FOR SIMPLE MAIN EFFECTS FOR VENTILATORY EQUIVALENT AT INITIAL MAXIMUM LOAD AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}^{2}_{33}F$ Crit.
Groups	343	171.72	2	9.70	α .01=5.31
Error	583	17.70	33		α .05=3.29

APPENDIX G-V11

(C) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR VENTILATORY EQUIVALENT AT INITIAL MAXIMUM LOAD AT POST TRAINING TEST

		3	1	2
	Means	30.435	24.492	23.408
2	23.408	**7.027	1.084	0.0
1	24.492	**5.492	0.0	
3	30.435	0.0		

**Significant at α =.01

Critical Values	r = 2	r = 3
q .99 (r,33) $\sqrt{MS}$ within/n	4.71	5.38
q .95 (r,33) $\sqrt{MS}$ within/n	3.50	4.22

APPENDIX G-V111

(A) THREE WAY ANALYSIS OF VARIANCE FOR OXYGEN PULSE (millilitres of oxygen per heart beat) AT INITIAL MAXIMUM LOAD.

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	491	35			
A	15	2	7.94	0.86	0.43
B	210	2	105	11.39	0.00
AB	16	4	4.05	0.44	0.77
Subj w Group	248	27	9.21		
Within Subj	45	36			
C	5.29	1	5.29	4.79	0.03
AC	2.28	2	1.14	1.03	0.36
BC	5.66	2	2.83	2.56	0.09
ABC	2.75	4	0.68	0.62	0.65
C X Subj W G	29.82	27	1.10		

APPENDIX H

STATISTICAL ANALYSIS OF DATA OBTAINED AT MAXIMUM WORK LOADS PRIOR TO AND AFTER TRAINING

APPENDIX H-1

(A) THREE WAY ANALYSIS OF VARIANCE FOR WORK LOADS AT MAXIMUM IN KILOPOND METRES PER MINUTE

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	3967808	35			
A	367504	2	183752	3.01	0.06
B	1929280	2	964640	15.78	0.00
AB	20624	4	5156	0.08	0.98
Subj w Group	1650400	27	61125		
Within Subj	1429296	36			
C	812832	1	812832	180.36	0.00
AC	472480	2	236240	52.42	0.00
BC	5680	2	2840	0.63	0.54
ABC	16752	4	4188	0.93	0.46
C X Subj W G	121680	27	4506		

(B) TEST FOR SIMPLE MAIN EFFECTS FOR MAXIMUM WORK LOADS (KPM/min) BETWEEN TREATMENTS AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}_{33}^{2}F$ Crit.
Groups	813728	406864.00	2	7.03	α .01=5.31
Error	1908736	57840.48	33		α .05=3.29

APPENDIX H-1

(C) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR MAXIMUM WORK LOADS (KPM/min) AT POST TRAINING TEST

		1	2	3
	Means	1887.500	1762.500	1525.000
3	1525.000	**362.500	*237.500	0.0
2	1762.500	125.000	0.0	
1	1887.500	0.0		

**Significant at α =.01

*Significant at α =.05

Critical Values	r = 2	r = 3
q .99 (r,33) $\sqrt{MS}$ within/n	270.08	308.96
q .95 (r,33) $\sqrt{MS}$ within/n	200.65	242.31

APPENDIX H-11

(A) THREE WAY ANALYSIS OF VARIANCE FOR MAXIMUM HEART RATES IN BEATS PER MINUTE

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	3937	35			
A	78	2	39	0.29	0.74
B	35	2	17	0.13	0.87
AB	223	4	55	0.42	0.79
Subj w Group	3601	27	133		
Within Subj	543	36			
C	44	1	44	2.90	0.10
AC	4	2	2	0.13	0.87
BC	46	2	23	1.51	0.23
ABC	39	4	9	0.64	0.63
C X Subj W G	410	27	15		

APPENDIX H-111

(A) THREE WAY ANALYSIS OF VARIANCE FOR MAXIMUM OXYGEN CONSUMPTION IN LITRES PER MINUTE

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	14.62	35			
A	1.15	2	0.57	2.79	0.07
B	7.49	2	3.74	18.16	0.00
AB	0.40	4	0.10	0.49	0.74
Subj w Group	5.57	27	0.20		
Within Subj	1.96	36			
C	0.70	1	0.70	26.19	0.00
AC	0.37	2	0.18	6.96	0.00
BC	.096	2	.048	1.79	0.18
ABC	.0057	4	.014	0.53	0.71
C X Subj W G	0.72	27	.027		

(B) TEST FOR SIMPLE MAIN EFFECTS FOR MAXIMUM OXYGEN CONSUMPTION (litres/min. at STPD) BETWEEN TREATMENTS AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}^{2}_{33}F$ Crit.
Groups	1	0.70	2	3.35	α .01=5.31
Error	6	0.21	33		α .05=3.29

APPENDIX H-111

(C) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR MAXIMUM OXYGEN CONSUMPTION (litres/min at STPD) AT POST TRAINING TEST

		2	1	3
	Means	3.480	3.423	3.035
3	3.035	*0.445	*0.388	0.0
1	3.423	0.057	0.0	
2	3.480	0.0		

*Significant at α =.05

Critical Values	r = 2	r = 3
q .99 (r,33) $\sqrt{MS}$ within/n	.505	.578
q .95 (r,33) $\sqrt{MS}$ within/n	.376	.443

APPENDIX H-1V

(A) THREE WAY ANALYSIS OF VARIANCE FOR MAXIMUM OXYGEN CONSUMPTION IN MILLILITRES PER KILOGRAM OF BODY WEIGHT PER MINUTE

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	1904	35			
A	70	2	35	2.24	0.12
B	1388	2	694	44.31	0.00
AB	22	4	5	0.36	0.83
Subj w Group	422	27	15		
Within Subj	290	36			
C	109	1	109	26.34	0.00
AC	56	2	28	6.79	0.004
BC	7	2	3	0.94	0.40
ABC	5	4	1	0.32	0.85
C X Subj W G	112	27	4		

(B) TEST FOR SIMPLE EFFECTS FOR MAXIMUM OXYGEN CONSUMPTION (ml per kg per minute at STPD) BETWEEN TREATMENTS AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}^{2}_{33}F$ Crit.
Groups	126	63.06	2	2.19	α .01=5.31
Error	948	28.76	33		α .05=3.29

APPENDIX H-V

(A) ONE WAY ANOVA FOR MAXIMUM OXYGEN CONSUMPTION (litres/min) AT STPD BETWEEN BLOCKS OF GROUP T70 AT PRE TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	$^{2}_{9}F$ Crit.
Groups	1	0.57	2	4.33	α .05=4.26
Error	1	0.13	9		

(B) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR MVO_2 (litres/min) AT STPD FOR BLOCKS IN T70 GROUP AT PRE TRAINING TEST

		3	2	1
	Means	3.542	3.180	2.785
1	2.785	*0.758	0.395	0.0
2	3.180	0.363	0.0	
3	3.542	0.0		

*Significant at α =.05

Critical Values	r = 2	r = 3
q .95 (r,9) $\sqrt{MS}$ within/n	.576	.711

(C) ONE WAY ANOVA FOR MVO_2 (litres/min) AT STPD BETWEEN BLOCKS OF GROUP T70 AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	$^{2}_{9}F$ Crit.
Groups	.42	0.21	2	1.01	α .01=8.02
Error	1.88	0.21	9		α .05=4.26

APPENDIX H-V

(D) ONE WAY ANALYSIS FOR MVO_2 (ml/kg/min) AT STPD BETWEEN BLOCKS OF GROUP T70 AT PRE TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	$^{2}_{9}F$ Crit.
Groups	276	138.33	2	12.61	α .01=8.02
Error	98	10.97	9		α .05=4.26

(E) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR MVO_2 (ml/kg/min) AT STPD FOR BLOCKS IN T70 GROUP AT PRE TRAINING TEST

		3	2	1
	Means	41.160	35.035	29.402
1	29.402	*11.758	*5.633	0.0
2	35.035	* 6.125	0.0	
3	41.160	0.0		

*Significant at α =.05

Critical Value	r = 2	r = 3
q .95 (r,9) $\sqrt{MS}$ within/n	5.28	6.52

(F) ONE WAY ANOVA FOR MVO_2 (ml/kg/min) AT STPD BETWEEN BLOCKS OF GROUP T70 AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	$^{2}_{9}F$ Crit.
Groups	147	73.83	2	3.32	α .01=8.02
Error	200	22.24	9		α .05=4.26

APPENDIX H-V1

(A) ONE WAY ANOVA FOR MVO_2 (litres/min) AT STPD BETWEEN BLOCKS OF GROUP T50 AT PRE TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}^{2}_{9}F$ Crit.
Groups	1.38	0.69	2	7.21	α .05=4.26
Error	.86	0.10	9		

(B) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR MVO_2 (litres/min) AT STPD FOR BLOCKS IN T50 GROUP

		3	2	1
	Means	3.547	3.155	2.715
1	2.715	*0.833	0.440	0.0
2	3.155	0.393	0.0	
3	3.547	0.0		

*Significant at α =.05

Critical Values	r = 2	r = 3
q .95 (r,9) $\sqrt{\text{MS within/n}}$	.480	.593

(C) ONE WAY ANOVA FOR MVO_2 (litres/min) AT STPD BETWEEN BLOCKS OF GROUP T50 AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}^{2}_{9}F$ Crit.
Groups	.81	0.41	2	3.62	α .05=4.26
Error	1.0	0.11	9		

APPENDIX H-V1

(D) ONE WAY ANALYSIS FOR MVO_2 (ml/kg/min) AT STPD BETWEEN BLOCKS OF GROUP T50 AT PRE TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	$^{2}_{9}F$ Crit.
Groups	215	107.70	2	17.08	α .01=8.02
Error	56	6.30	9		α .05=4.26

(E) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR MVO_2 (ml/kg/min) AT STPD FOR BLOCKS IN T50 GROUP AT PRE TRAINING TEST

		3	2	1
	Means	40.775	34.597	30.465
1	30.465	*10.310	*4.132	0.0
2	34.597	* 6.177	0.0	
3	40.775	0.0		

*Significant at α =.05

Critical Value	r = 2	r = 3
q .95 (r,9) $\sqrt{MS}$ within/n	4.00	4.94

(F) ONE WAY ANOVA FOR MVO_2 (ml/kg/min) AT STPD BETWEEN BLOCKS OF GROUP T50 AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	$^{2}_{9}F$ Crit.
Groups	153	76.75	2	8.21	α .01=8.02
Error	84	9.35	9		α .05=4.26

APPENDIX H-V1

(G) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR $M\dot{V}O_2$ (ml/kg/min) AT STPD FOR BLOCKS IN T50 GROUP AT POST TRAINING TEST

		3	2	1
	Means	43.917	38.917	35.187
1	35.187	*8.730	3.730	0.0
2	38.917	5.000	0.0	
3	43.917	0.0		

*Significant at α =.05

Critical Value	r = 2	r = 3
q .95 (r,9) $\sqrt{MS}$ within/n	4.86	6.00

APPENDIX H-V11

(A) THREE WAY ANALYSIS OF VARIANCE FOR MAXIMUM PULMONARY MINUTE VENTILATION IN LITRES PER MINUTE (STPD)

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	29606	35			
A	472	2	236	0.40	0.67
B	10786	2	5393	9.07	0.00
AB	2285	4	571	0.96	0.44
Subj w Group	16062	27	594		
Within Subj	2463	36			
C	201	1	201	3.11	0.08
AC	99	2	49	0.77	0.47
BC	177	2	88	1.37	0.27
ABC	240	4	60	0.93	0.46
C X Subj W G	1744	27	64		

APPENDIX H-V111

(A) THREE WAY ANALYSIS OF VARIANCE FOR BLOOD LACTATE CONCENTRATIONS (mg%) AT MAXIMUM WORK

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	21045	35			
A	2112	2	1056	1.93	0.16
B	2163	2	1081	1.98	0.15
AB	2003	4	500	0.92	0.46
Subj w Group	14766	27	546		
Within Subj	5906	36			
C	624	1	624	4.82	0.03
AC	957	2	478	3.69	0.03
BC	316	2	158	1.22	0.31
ABC	512	4	128	0.99	0.43
C X Subj W G	3497	27	129		

(B) TEST FOR SIMPLE MAIN EFFECTS FOR MAXIMUM BLOOD LACTATE CONCENTRATIONS (mg%) BETWEEN TREATMENTS AT PRE-TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	$^{2}_{33}F$ Crit.
Groups	2956	1478.00	2	3.57	α .01=5.31
Error	13680	414.55	33		α .05=3.29

APPENDIX H-V111

(C) NEWMAN-KEULS COMPARISON BETWEEN ORDERED MEANS FOR MAXIMUM BLOOD LACTATE CONCENTRATIONS (mg%) AT PRE-TRAINING TEST

		3	2	1
	Means	100.083	82.333	79.667
1	79.667	*20.417	2.667	0.0
2	82.333	*17.750	0.0	
3	100.083	0.0		

*Significant at α = .05

Critical Values	r = 2	r = 3
q .99 (r,33) $\sqrt{\text{MS}}$ within/n	22.88	26.17
q .95 (r,33) $\sqrt{\text{MS}}$ within/n	16.99	20.52

(D) TEST FOR SIMPLE MAIN EFFECTS FOR MAXIMUM BLOOD LACTATE CONCENTRATIONS (mg%) BETWEEN TREATMENTS AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	$^{2}_{33}$ F Crit.
Groups	113	56.56	2	0.19	α .01=5.31
Error	9577	290.23	33		α .05=3.29

APPENDIX H-1X

(A) THREE WAY ANALYSIS OF VARIANCE FOR VENTILATORY EQUIVALENT AT MAXIMUM WORK

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	1522	35			
A	132	2	66.03	1.51	0.23
B	69	2	34.99	0.80	0.45
AB	140	4	35.08	0.80	0.53
Subj w Group	1180	27	43.70		
Within Subj	159	36			
C	7.61	1	7.61	1.66	0.20
AC	8.64	2	4.32	0.94	0.40
BC	6.75	2	3.37	0.74	0.48
ABC	12.32	4	3.08	0.67	0.61
C X Subj W G	123	27	4.58		

APPENDIX H-X

(A) THREE WAY ANALYSIS OF VARIANCE FOR MAXIMUM OXYGEN PULSE IN MILLILITRES OF OXYGEN PER HEART BEAT

SUMMARY OF ANALYSIS OF VARIANCE

Source	SS	DF	MS	F	P
Bet Subj	531.16	35			
A	37.94	2	18.97	1.98	0.15
B	221.36	2	110.68	11.57	0.00
AB	13.64	4	3.41	0.36	0.83
Subj w Group	258.22	27	9.56		
Within Subj	60.62	36			
C	26.56	1	26.56	42.81	0.00
AC	13.43	2	6.71	10.83	0.00
BC	2.47	2	1.23	1.99	0.15
ABC	1.39	4	0.34	0.56	0.69
C X Subj W G	16.75	27	0.62		

(B) TEST FOR SIMPLE MAIN EFFECTS FOR MAXIMUM OXYGEN PULSE IN MILLILITRES OF OXYGEN PER HEART BEAT AT POST TRAINING TEST

ANALYSIS OF VARIANCE

Source	SS	MS	DF	F	${}_{33}^{2}F$ Crit.
Groups	48	24.11	2	3.14	α .01=5.31
Error	253	7.69	33		α .05=3.29

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